# Pathways to a greener China

A master thesis on examining the influences of the elements of the theory of planned behavior on different aspects of a low-carbon lifestyle among Chinese consumers. Focussing specifically on a low-carbon diet, transport & shopping behavior and examining the potential modulating of socioeconomic factors

*Master thesis*

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## Prologue

First and foremost, I would like to express my gratitude to my supervisor from Utrecht University, Jiamin Ou. Your involvement, guidance, and insightful perspectives have played an important role in writing this master's thesis. Additionally, I would like to thank my second supervisor, Wojtek Przepiorka, for the time he dedicated to reviewing my thesis. I have enjoyed working on this research and am grateful for the guidance I have received throughout this process.

## Abstract

This study utilizes the Theory of Planned Behavior (TPB) to investigate the influence of TPB elements on the adoption of a low-carbon lifestyle among Chinese consumers, covering various aspects including diet, transport and shopping behavior for a holistic view. According to TPB, attitude, subjective norms, and perceived behavioral control (PBC) are key determinants of behavioral intentions. In this study, PBC is measured by knowledge of climate impact and barriers to a low-carbon lifestyle. Additionally, this study examines how socioeconomic factors including gender, age, and income potentially modulate these relationships. Two SEM (structural equation modeling) models are performed, to analyze the direct and moderating effects of the TPB elements on the various aspects of a low-carbon lifestyle. Results show that subjective norms and barriers to a low-carbon lifestyle, influence all three aspects of low-carbon lifestyle in a consistent way. In contrast, subjective norms exert a consistently positive influence on the adoption of a low-carbon lifestyle, whereas barriers exert a consistently negative influence. Effects of attitude and knowledge of climate impact, vary depending on the specific aspect. Attitude only exerts a significant positive effect on transport and a non-significant effect on diet and shopping behavior. Knowledge yields positive influences on all aspects, but the strength of the effect differs. This research uncovers the nuances between TPB elements and aspects of a low-carbon lifestyle as they can be different dependent on the TPB element and aspect of a low-carbon lifestyle. In some cases, socioeconomic factors were found to significantly moderate the relationships. The results of this study underscore the importance of promoting social support and knowledge of climate impact and the value of eliminating potential barriers, to enhance the adoption of a low-carbon lifestyle. This study contributes to the literature by providing a comprehensive analysis of different aspects of a low-carbon lifestyle, rather than focusing on a single aspect or merging all aspects into one. The insights gained in this study can be used as policy recommendations to help China achieve its climate goals in the future.

**Keywords**: low-carbon lifestyle, Theory of Planned Behavior (TPB), sustainable behavior, socioeconomic factors, structural equation modeling (SEM), China.

# Table of content

## 1. Introduction

There is an urgent need for international cooperation in the fight against climate change. Recent global agreements such as the Paris Agreement, signed by almost all countries, have been made to limit global warming to less than 2 degrees Celsius, with efforts to limit it to 1.5 degrees (United Nations Framework Convention on Climate Change, 2015). These global agreements also define national contributions to detail each country's specific climate actions and goals. As the two largest emitters of greenhouse gases, China and the United States are key to achieving the globally established goals (International Energy Agency (IEA), 2020).

China, in particular, is the subject of much research because of its substantial contribution to global pollution. The environmental impacts of China's emissions are severe, leading to consequences such as flooding, extreme droughts, loss of biodiversity, mass animal mortality, heatwaves, and intensified storms (Mariappan et al., 2023). Climate scientists warn that at the current emission rates, the earth will exceed its carbon budget for limiting the temperature rise to 1.5 degrees Celsius in less than six years (Tebbens, 2023).

In response, China has implemented strict environmental regulations and established ambitious climate goals (Wu, 2023). For example, in September 2020, China announced that its annual carbon dioxide emissions would peak in 2030 and then decline, with a goal of becoming carbon neutral by 2060. This commitment aligns with United Nations Sustainable Development Goal 12, which emphasizes responsible production and consumption (United Nations Framework Convention on Climate Change, 2015). China has already made significant progress in recent years: it met more than half of its reduction targets last year and is well on its way to becoming a low-carbon nation (Tsinghua University School of Economics and Management, 2023).

Several studies show that public participation and collective awareness are essential for making China more sustainable (Huang, 2020; Li et al., 2018; Liu et al., 2018). To foster public participation, it is necessary to study individual sustainable behavior and how intentions to engage in such behavior arises. In other words, what factors lead an individual to adopt a low-carbon lifestyle? Hereby, a low-carbon lifestyle involves a way of living that significantly reduces one’s carbon footprint, mainly through changes in consumption patterns and behaviors. This concept includes a wide range of actions aimed at minimizing greenhouse gas emissions from daily activities such as transportation, energy use, diet, and waste management (Koide et al., 2021).

The Theory of Planned Behavior (TPB) provides a framework for explaining and influencing human behavioral intentions (Ajzen, 1991). According to TPB, the intention to engage in a specific behavior is influenced by three elements: attitude, subjective norms, and perceived behavioral control (PBC).

To begin with, attitude indicates an individual's stance towards a specific behavior. When this attitude is positive, it is expected that the individual will be more inclined to exhibit this behavior. Furthermore, subjective norms refer to the perceived attitude towards certain behavior in one's environment. This can be seen as a form of *social pressure*; the phenomenon in which an individual is more likely to engage in certain behavior when their social group adheres to it (Asch, 1955). Perceived behavioral control (PBC), finally, indicates an individual's perception of their ability to perform the behavior. If an individual believes he or she possesses the necessary resources and skills to perform a certain behavior, they will be more likely to perform that behavior (Ajzen, 1991).

Previous studies have found significant effects of the TPB-elements on various aspects of a low-carbon lifestyle. To illustrate, a meta-analysis by Biasini et al. (2021) revealed that in numerous studies, attitude was found to be a significant predictor of a low-carbon diet. Furthermore, Zhu et al. (2020) found that subjective norms exert a positive influence on sustainable transport choices, but Kumar (2012) showed that subjective norms did not have a significant effect on low-carbon shopping behavior. Additionally, Klöckner (2021) demonstrated that PBC, among other factors, was a significant predictor of sustainable behavior in his study. In short, there are numerous studies utilising the TPB to predict sustainable behavior. But most of these studies primarily focused on the effect of TPB elements on a low-carbon lifestyle in general or just one aspect of it (Biasini et al, 2021; Hassan et al., 2018; Heeren et al., 2016; Kumar, 2012; Klöckner, 2021; Ogiemwonyi et al., 2023; Rex et al., 2015; Zhu et al. 2020). However, there is a lack of research examining multiple different aspects of a low-carbon lifestyle simultaneously. A low-carbon lifestyle consists of a variety of different aspects, from energy consumption to diet to consumption behavior. For some people, a low-carbon diet may be more feasible than choosing low-carbon transport, or vice versa. This research aims to fill this gap by examining the influences of TPB elements on various aspects of a low-carbon lifestyle to gain a holistic understanding of these influences.

Socioeconomic factors also play a crucial role in determining a person's sustainable behavior, interacting significantly with elements of the TPB. A number of studies have demonstrated that females are more susceptible to the influences of the TPB than males, which results in a greater propensity for a low-carbon lifestyle among females. For instance, research

on shared bicycle use in China demonstrated that females' behavior was more influenced by subjective norms and PBC compared to males. Additionally, other research has indicated that females generally display higher environmental concern and are more influenced by subjective norms in their sustainable purchasing decisions (Xin et al., 2019). In contrast, for males, PBC was found to be a more significant predictor of sustainable purchasing behavior, as it provides them with a more practical and controllable approach to sustainable behavior (Wijekoon & Sabri, 2021). In addition to gender, age is also a socioeconomic factor that can have a significant impact on the elements of the TPB and the adoption of a low-carbon lifestyle. For instance, Johnstone & Lindh (2022) investigated the mediating influence of age and found that in their study, younger individuals, namely millennials, were more sensitive to the norms in their environment. Finally, income can also be considered an important socio-economic factor within this context. To illustrate, a meta-analysis of several studies demonstrated a positive correlation between income and positive attitudes towards sustainable behavior (Franzen & Vogl, 2013; Szulc-Obłoza & Żurek, 2024). Accordingly, this study considers socioeconomic factors such as gender, age, and income, as these factors can influence the effect of TPB elements and therefore the likelihood of individuals adopting a low-carbon lifestyle (Mueller & Parcel, 1981).

The promotion of low-carbon lifestyles represents a significant opportunity to reduce the emissions generated by households, which account for a substantial part of the total global greenhouse gas emissions (Tian et al., 2016). With many Chinese residents experiencing substantial economic growth, they have larger budgets to spend on improving their quality of life, often resulting in the purchase of energy-intensive products and increased travel by plane (Dai et al., 2012). This trend is reflected in the numbers: China's total CO2 emissions accounted for 31% of global fossil fuel CO2 emissions in 2022 and this increased in the decade prior 2022, while the emissions of both Europe and the US decreased (Friedlingstein et al., 2023). Considering the components of these emissions, China's food system was responsible for around 2.4 gigatons of $CO_2$ equivalent in 2019. The percentage of total emissions due to dietary choices that year was therefore approximately 17.02% (Larsen et al., 2021; Liu et al., 2023). Moreover, China's transportation sector grew, and both oil and coal consumption increased significantly. As a result, emissions from transport rose proportionally to around 1.3 gigatons of $CO_2$ equivalent, making up approximately 9.2% of total emissions (Pei-Ning et al., 2023). Lastly, the share of shopping behavior is more difficult to approach as shopping behavior covers multiple different areas such as clothes, food and other household items. When examining the emissions of the fashion industry, it becomes clear that this industry is estimated to be responsible for 8 to 10% of total global emissions, making it a significant polluter in the world

(Manieson & Ferrero-Regis, 2023). Although this does not directly reflect emissions from Chinese households' shopping behavior, it is closely related since a large portion of the clothing that is made, is intended for households.

This research utilizes data collected from 3666 Chinese respondents via the social media platform WeChat. It stands as one of the pioneering studies to examine distinct aspects of a low-carbon lifestyle while also considering the influence of an individual's socioeconomic factors. The aim is to gain a better understanding of how different aspects of a low-carbon lifestyle can be influenced by TPB elements and how socioeconomic factors play a role within this relation. The research specifically focuses on individuals' behavioral intentions, how these intentions can be influenced and how this knowledge can be used in policy recommendations on low-carbon lifestyles in China. To gain these insights, empirical scientific research is combined with data from a questionnaire administered to a significant sample of respondents.

This research aims to contribute to the scientific field by focusing on the influences of TPB elements on different aspects of a low-carbon lifestyle. The research question central to this thesis is therefore: "*How do attitude, subjective norms, and perceived behavioral control influence the adoption of low-carbon lifestyle choices in terms of diet, transport and shopping behavior, and how do socioeconomic factors (gender, age, and income) modulate these effects?"*

The following paragraph introduces the theoretical framework underlying the analysis of factors influencing a low-carbon lifestyle. This includes a literature review of previous research on sustainable behavior in China and other countries and a description of the TPB elements: attitudes, subjective norms and perceived behavioral control, as well as the role of socioeconomic factors. The subsequent methods section describes the measurement and structural model, the different structural equation models (SEMs), assumptions of SEM, data specifications, operationalizations, and distributions of the variables, as well as the model fit. Subsequently, the results of the analyses are discussed, starting with the correlations, and then presenting the SEM analysis of the model without and with direct effects and interaction terms of the socioeconomic factors. Finally, the key findings, strengths, and limitations of this study are discussed, along with policy implications and recommendations for future research.

## 2. Literature review

This chapter presents the theoretical framework based on the research question. This includes an exploration of theories related to the elements of the Theory of Planned Behavior (TPB) and their relationship with various aspects of a low-carbon lifestyle. First, a broad overview of current knowledge and research in China and other developed countries is presented. Then, the theory of planned behavior (TPB) is outlined, followed by a review of research on the effects of attitude, subjective norms, and perceived behavioral control. Additionally, socioeconomic factors and their potential influence on the effects of the TPB elements on a low-carbon lifestyle are theoretically examined. The chapter concludes with the presentation of the hypotheses.

### *2.1 Existing knowledge in the Chinese context*

Previous studies have examined influences of TPB elements on aspects of low-carbon lifestyles in China extensively. For instance, Liu et al (2017) found that in Tianjin, China, personal norms exert a large influence on low-carbon transport intention and Bai et al. (2019) showed that in China, norms from family members and other people in an individuals' close circle, can have a strong influence on an individual's sustainable food purchase behavior.

Rapid urbanization and economic growth create both opportunities and challenges in terms of low-carbon lifestyles in China. Recent studies found that introducing subsidies can be an important incentive to purchase an electric vehicle or choose public transport (Zhu et al., 2020; Liu et al., 2016).

However, many studies often examine aspects of a low-carbon lifestyle separately or consider the low-carbon lifestyle as a single entity. In both types of research, the effect of TPB elements on separate aspects of a low-carbon lifestyle cannot be compared.

### *2.2 Comparison to other developed countries*

When China and other developed countries such as European countries and the United States are compared, it is noticeable that China faces its own challenges as it is at a different stage in terms of its development and economy. In recent years, China has initiated several campaigns to encourage a low-carbon lifestyle. For instance, China came up with programmes such as Personal Carbon Trading (PCT) to increase citizens' participation in low-carbon practices. In addition, it has introduced Inclusive Carbon Credits (ICC) to enable people to earn and trade carbon credits, thus encouraging sustainable behavior (Xu et al., 2023).

The EU and the US have also set up important regulations and frameworks. These include the EU's Green Deal, and the fact the US has acceded to the Paris agreement under the Biden government. In this, the EU and the US are leading the way by having stricter rules and higher carbon taxes than China in many areas (World Bank Group, 2022).

*2.3 Theory of Planned Behavior*

One of the most widely used and leading theories in predicting individual intentions is the Theory of Planned Behavior (Ajzen, 1991). Figure 1 visually represents the model of the theory. As shown in the model, the elements attitude, subjective norm, and perceived behavioral control, previously mentioned and defined, stem from behavioral beliefs, normative beliefs, and control beliefs, respectively. Here, behavioral beliefs refer to the expected consequences of performing the specific behavior, normative beliefs refer to beliefs about the normative expectations of significant others, and control beliefs refer to beliefs about the feasibility of performing the specific behavior. Behavioral, normative, and control beliefs, in turn, originate from various background factors; a combination of the individual's upbringing circumstances and the environmental and social influences they face (Ajzen, 1999).

The intention for specific behaviors of an individual arises thus from various internal and external processes. To provide guidance in this complex interplay, the TPB is commonly employed in many studies to explain behavioral intentions. Specifically for predicting sustainable intentions, the TPB has proven fruitful in numerous studies (Chen, 2016; Kaplan et al., 2015; Wicaksono et al., 2020; Wu et al., 2021). For this reason, the TPB elements will also serve as the basis for explaining intentions of sustainable behavior in this research.

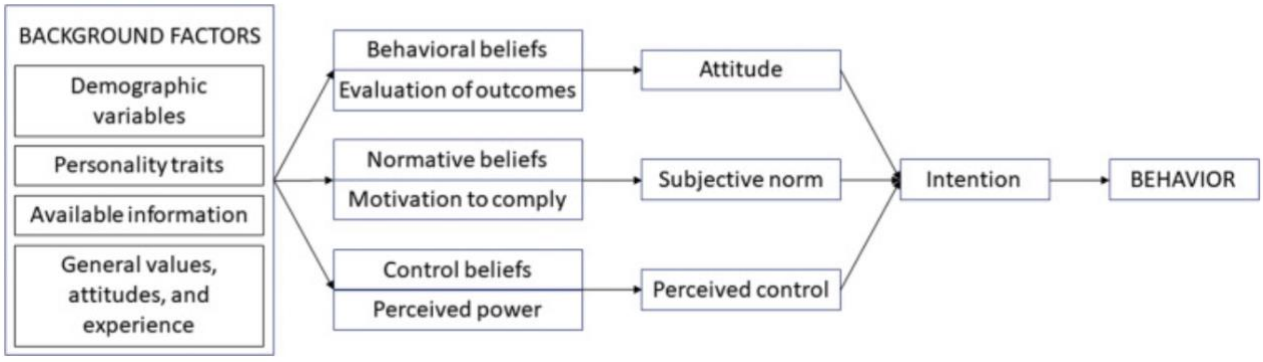


***Figure 1.*** Model of the theory of planned behavior (TPB)

*Note*. From *Chapter 90 - Implementation research* by James C. Etheridge, Robert D. Sinyard, Mary E. Brindle, in *Translational Surgery*, 2023

*2.4 Attitudes regarding a low-carbon lifestyle*

Various studies indicate that an individual's attitude towards sustainable behavior is a significant factor in promoting sustainable behavior (Chen, 2016; Kaplan et al., 2015). When examining the aspects of a low-carbon lifestyle that are central to this study, it is evident that attitude often has a clear, positive influence on adopting a more low-carbon lifestyle. However, in many cases, a positive attitude alone is not sufficient to fully adopt a low-carbon lifestyle. In this section, the influence of attitude on diet will first be elaborated upon, followed by its impact on transport and shopping behavior.

In studies focusing on the influence of attitude on adopting a sustainable diet, positive attitudes towards sustainable food have been shown to be an important component of sustainable eating behavior (Biasini et al., 2021). A sustainable diet includes consuming food that is sustainably produced and involves considering economic, social, and ecological factors to produce food without jeopardizing nutrition for future generations and minimizing the ecological footprint of the diet (Kenny et al., 2023). Nonetheless, not all studies support that a positive attitude towards sustainable food leads to more sustainable food choices. For instance, Vermeir & Verbeke (2006) indicate that there is still a clear gap between a positive attitude towards a sustainable diet and an actual intention to adopt a sustainable diet. Their paper suggests that, in the case of their research, this gap arises from a perceived low availability of sustainable food options, which leads to a lack of intention to adopt a sustainable diet. On the other hand, their study suggests that positive subjective norms towards a sustainable diet do significantly predict a sustainable diet, even when there is a negative attitude towards a sustainable diet. This supports the importance of considering the interaction between the factors of the TPB in predicting sustainable behavior in research.

When examining the influence of attitude on the adoption of sustainable transportation behavior, it is found that a positive attitude towards taking the bus can lead to increased bus usage, a form of low-carbon transport (Heath & Gifford, 2002). Other research conducted in Tianjin, China, found that attitudes towards the use of public transportation influence the acceptance of policies aimed at promoting sustainable public transport. In addition to attitudes, the researchers also found that owning a car and having a longer commuting time indirectly exerts a negative influence on the use of public transportation (Liu et al., 2016).

Finally, when examining the influence of attitude on the more sustainable purchasing of clothing, it appears that sustainable attitudes are essential for sustainable clothing purchases (Jacobs et al., 2018). Additionally, Jacobs et al. (2018) indicate that, along with attitudes, an individual's *values* exert significant influence on sustainable clothing purchases. Values can be

defined within this context as an individual's core life principles that are also less volatile than attitudes and change minimally over time (Rokeach, 1973; Spates; 1983; Schwartz, 1994). This again underscores the importance of considering the interaction between the factors of the TPB, as these *values* are often strongly influenced by the subjective norms within an individual's core network.

### *2.5 Subjective norms regarding a low-carbon lifestyle*

In addition to attitude, subjective norms also influence intentions to adhere to sustainable behaviors (Swaim et al., 2014). Studies frequently show a strong positive influence of subjective norms on adopting a low-carbon lifestyle. In this section, the influence of subjective norms on diet in previous studies will be discussed first, followed by their influence on transport and shopping behavior.

As previously mentioned, positive subjective norms towards a sustainable diet can predict sustainable diet choices even when there is a negative attitude towards sustainable eating behavior (Vermeir & Verbeke, 2006). Due to the social pressure individuals feel from their environment, they are thus more inclined to make sustainable choices, also in terms of their diet.

This also seems to apply to sustainable transport choices. For instance, research on bike-sharing in China showed that subjective norms positively impact these more sustainable transportation choices (Zhu et al., 2020). These findings show that one's social context and group norms are influential in promoting sustainable behavior. Zhu et al. (2020) suggest that social support and prompting behavior from the environment can contribute to an individual's choice of more sustainable transport options, such as bike sharing and public transport.

When examining the influence of subjective norms on adopting an intention for more sustainable purchasing of clothing, it is found that subjective norms also seem to exert influence on this behavior (Saricam & Okur, 2018). Saricam & Okur (2018) found that the normative expectations experienced by individuals play a role in this regard: individuals tend to conform to what they perceive as social expectations and norms within their social groups. If individuals believe that their social environment values and expects sustainability, they are more likely to align their shopping behavior with these norms in order to get approval and acceptance from their social environment.

*2.6 Perceived behavioral control regarding a low-carbon lifestyle*

The third element of the TPB, perceived behavioral control, has been shown to exert a significant influence on sustainable behavior (Chauhan & Bhagat, 2018; Gardner & Abraham, 2007).

Biasini et al. (2021) demonstrated in their research that perceived behavioral control is a significant predictor of sustainable eating behavior. They propose a valuable strategy of enhancing meal planning and preparation to boost individuals' sense of control and ability to adhere to sustainable eating behavior, thereby fostering a more low-carbon lifestyle.

Furthermore, in studies examining the impact of perceived behavioral control on the intention to engage in sustainable transportation behavior, it has been found that high levels of perceived behavioral control are associated with reduced car usage and increased intention to use public transportation (Gardner & Abraham, 2007).

As previously mentioned, sustainable attitudes are essential for sustainable purchases (Jacobs et al., 2018). However, there are also studies that acknowledge that individuals with a positive attitude towards sustainable purchasing behavior may not necessarily have the intention to purchase sustainably when faced with difficulties (Chen, 2007). These difficulties may include the price of products or their availability (Carrigan & Attalla, 2001; Vermeir & Verbeke, 2006). In such cases, a strong sense of perceived behavioral control is crucial for the intention to engage in more sustainable purchasing behavior (Chauhan & Bhagat, 2018).

*2.7 Socioeconomic factors*

In addition to the TPB elements, there may be other elements that could influence and predict an intention towards a low-carbon lifestyle. Sustainable behavior is complex and comprised of various aspects (Jager & Mosler, 2007). It is expected that one's socioeconomic status could also play a role in this context.

Previous research shows that an individual's income can be a significant barrier in making sustainable decisions. Sustainable choices are often more expensive, and when finances do not permit a sustainable lifestyle, this could significantly impact an individual's decision to opt for a pricier, sustainable alternative. Hence, it can be concluded that one's socioeconomic status can indeed influence their intention towards sustainable behavior (De Groot & Steg, 2008).

However, socioeconomic status includes more than just income; educational level is also a component of one's socioeconomic status (Mueller & Parcel, 1981). Individuals with higher levels of education and, therefore, a higher socioeconomic status, also have greater

access to education and knowledge about sustainable options (Nielsen, 2023). Research indicates that individuals with more knowledge about sustainable options are more likely to choose these sustainable alternatives (Jager & Mosler, 2007). As this study does not have access to data on the educational level of the respondents, educational level cannot be included as one of the socioeconomic factors. However, previous research indicates the importance of including educational level, and it is therefore recommended for future research.

Nevertheless, this may not necessarily apply to all sustainable behaviors: research conducted with Iranian households found that individuals with higher socioeconomic status had less sustainable diets. Specifically, individuals with higher socioeconomic status consumed proportionally more animal products than those with lower socioeconomic status (Eini-Zinab et al., 2021). Moreover, the viability of public transport as a more sustainable choice for people with higher socio-economic status seems to be questionable: as Chinese commuters' incomes rise, they are increasingly inclined to buy private cars for their families (Linn & Shen, 2024).

When examining specific components of socioeconomic status, gender can also be considered an influential factor. Various previous studies have shown that females are important players in achieving global climate goals, as household energy consumption accounts for 35% of total energy consumption, and females are still mainly responsible for household management in many cultures, including China (Habtezion, 2016; Shrestha et al., 2021; Qing, 2020). On the other hand, research shows that males tend to have a larger ecological footprint than females, for example by eating more meat than females and using more services that contribute to climate change (Ritzel & Mann, 2021; Widegren & Sand, 2021). Females are more likely to have positive attitudes towards environmental policies and are more likely to participate in activities that promote sustainability, such as community vegetable gardening and local environmental groups. Males are also concerned about environmental issues, but often prefer technological solutions to address the environmental problem (Widegren & Sand, 2021).

Furthermore, research shows that individuals of different ages have different perspectives on a low-carbon lifestyle and, in some cases, act differently. For instance, Johnstone & Lindh (2022) investigated the mediating influence of age and found that in their study, younger individuals, namely millennials, were more sensitive to the norms in their environment and that 'influencers' could increase sustainability awareness within this group. However, other research has shown that older individuals are more likely to be conscious of the earth and its resources and to reduce environmental damage (Wiernik et al., 2013).

Thus, the relationship between socioeconomic factors and a low-carbon lifestyle appears to be a complex one. However, this complexity makes it all the more interesting to include these

factors in the study of TPB elements. Although it is not yet clear exactly how socioeconomic factors will influence the relationships, it is expected that these factors will influence the relationships to some extent. Given the sometimes conflicting expected effects, it is particularly important to look at the influence of socio-economic factors on separate aspects of a low-carbon lifestyle.

The following hypotheses are addressed in this study:

- **H1**: Attitude has a positive effect on the adoption of a low-carbon lifestyle, regarding diet, transport, and shopping behavior, among Chinese consumers.
- **H2**: Subjective norms have a positive effect on the adoption of a low-carbon lifestyle, regarding diet, transport, and shopping behavior, among Chinese consumers.
- **H3**: Perceived behavioral control has a positive effect on the adoption of a low-carbon lifestyle, regarding diet, transport, and shopping behavior, among Chinese consumers.
- **H4**: Socioeconomic factors (gender, age and income) modulate the effect of the TPB elements on the adoption of a low-carbon lifestyle, regarding diet, transport, and shopping behavior, among Chinese consumers.

# 3. Methodology

In this paragraph the research design is outlined. The path diagram of the analyses, the measurement model, structural equation modeling (SEM) models and the assumptions of the analyses, are all covered in the first section. While the SEM analysis of the model with interaction terms provides insight on how these interactions differ among various demographic groups, the SEM analysis of the model without interaction terms offers a foundational understanding of the main relationships. In the second part, the data collection, the operationalizations and distributions of the variables utilized in this study, are covered.

## *3.1 Structural equation modeling (SEM)*

To test the hypotheses, two structural equation modeling (SEM) models are employed. It can be argued that SEM represents a more appropriate technique for analysis when compared with multiple regression. This is due, in part, to SEM's ability to deal with multiple dependent variables, include latent variables, account for measurement error and specify complex relationships in a single model (Hoyle, 1995). This makes it a highly robust statistical technique which is well suited to the complexity of the research question in this study. Several previous studies utilising the TPB have also employed the use of SEM as a research method. The results obtained in these studies have demonstrated that it is a successful methodology (Behjati et al., 2012; Kumar, 2012; Liao et al., 2023; Liu et al., 2020).

## *3.2 Path diagram*

Figure 2 presents the path diagram for the hypothesized structural equation model (SEM) used in this study. The diagram visually represents the relationships among key variables: attitude, subjective norms, and perceived behavioral control, and how they affect three observed outcome variables: diet, transport, and shopping behavior. The direct and moderating effects of socioeconomic factors are also included in the model. The interaction terms are shown with dashed arrows, indicating their influence on the primary relationships. The latent variables are illustrated in a circle, while the observed variables are shown in a square, in accordance with the usual format for path diagrams within a SEM analysis. Note that figure 2 represents the path diagram of the SEM analysis of the model *with* the direct effects and interaction terms of the socioeconomic factors. The path diagram of the model *without* the socioeconomic factors factors would look similar but would exclude the lower blue square and accompanying arrows.

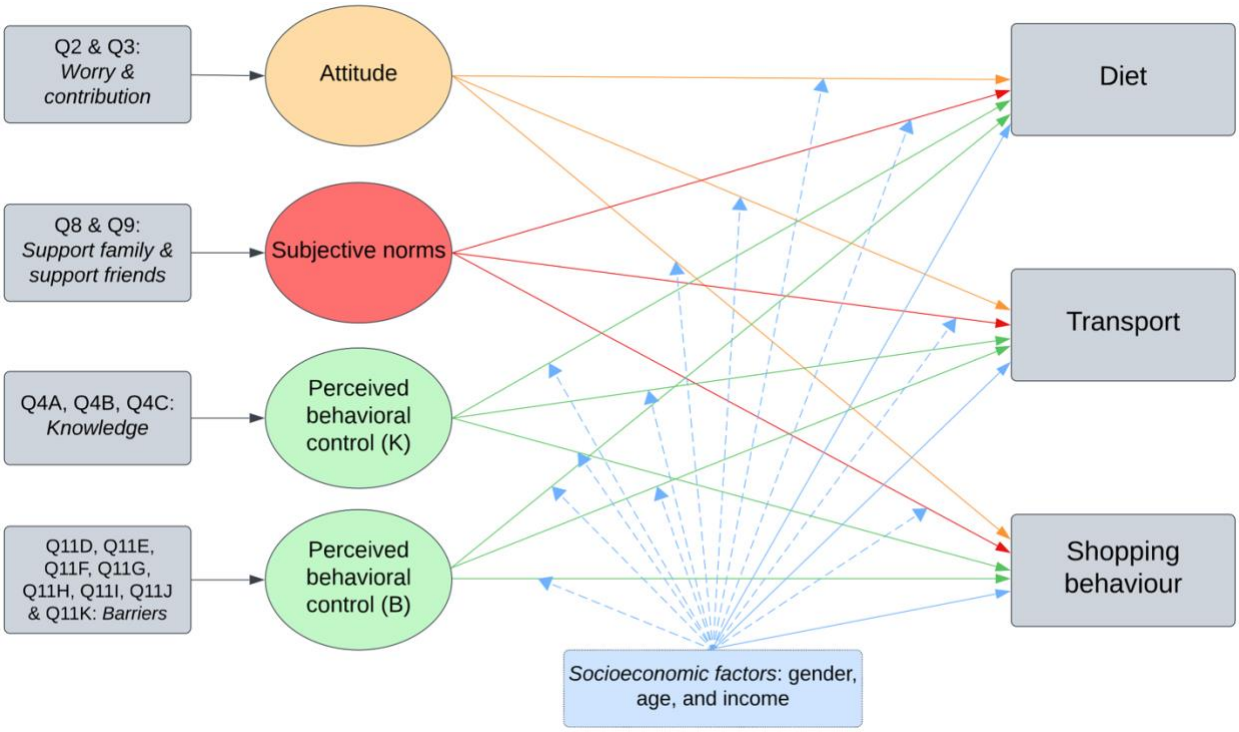


***Figure 2.*** Path diagram of the SEM analysis of the model *with* the direct effects and interaction terms of the socioeconomic factors, the path diagram of the model *without* interaction terms would look similar but would exclude the lower blue square and accompanying arrows

### *3.3 Measurement model*

On the left side of figure 2, the indicators of the latent variables are displayed. To begin with, attitude is a latent variable measured by two observed indicators: how worried the respondent is about the impact of climate change and to what extent they believe personal lifestyle choices can contribute to addressing climate change. Additionally, subjective norms is also a latent variable measured by two observed indicators: support from family and support from friends. Finally, perceived behavioral control consists of two latent variables: knowledge and barriers, which include four indicators for the respondent's knowledge and eight indicators for the potential barriers to adopting a low-carbon lifestyle. This approach was chosen because it was not feasible to create a single latent variable from these indicators due to the significantly different measurement methods of the questions. This is discussed and explained in more detail in section 3.3.3.

The latent variables are constructed according to the formulas displayed on the following page. In these formulas, $\lambda$ stands for the loading factor of the indicator. Loading factors illustrate the relationship between latent variables and their corresponding indicators (Bollen & Hoyle, 2012). They demonstrate the extent to which the indicators (the measured variables) correspond to the latent constructs: the concepts that cannot be directly measured,

which are attitude, subjective norms, and PBC in this study. The loading factors within this study are typically robust and statistically significant, suggesting a reliable and valid measurement of the latent constructs. Appendix II provides an overview of the values of the loading factors. It should be noted that the loading factor of the first indicator is fixed at 0. This is a standard practice in SEM that helps with model identification, latent variable scaling and the comparison between indicators (Bollen & Hoyle, 2012).

***Attitude***

$Worry = \lambda 1 \times Attitude + \epsilon 1$

$Contribution = \lambda 2 \times Attitude + \epsilon 2$

***Subjective norms***

$Support\ family = \lambda 3 \times Subjective\ norms + \varepsilon 3$

$Support\ friends = \lambda 4 \times Subjective\ norms + \varepsilon 4$

***PBC1: Knowledge of climate impact***

$Knowledge\ diet = \lambda 5 \times Knowledge\ of\ climate\ impact + \varepsilon 5$

$Knowledge\ transport = \lambda 6 \times Knowledge\ of\ climate\ impact + \varepsilon 6$

$Knowledge\ shopping\ behavior = \lambda 7 \times Knowledge\ of\ climate\ impact + \varepsilon 7$

***PBC2: Barriers to a low-carbon lifestyle***

$Barrier1 = \lambda 8 \times Barriers\ to\ a\ low-carbon\ lifestyle + \varepsilon 8$

$Barrier2 = \lambda 9 \times Barriers\ to\ a\ low-carbon\ lifestyle + \varepsilon 9$

$Barrier3 = \lambda 10 \times Barriers\ to\ a\ low-carbon\ lifestyle + \varepsilon 10$

$Barrier4 = \lambda 11 \times Barriers\ to\ a\ low-carbon\ lifestyle + \varepsilon 11$

$Barrier5 = \lambda 12 \times Barriers\ to\ a\ low-carbon\ lifestyle + \varepsilon 12$

$Barrier6 = \lambda 13 \times Barriers\ to\ a\ low-carbon\ lifestyle + \varepsilon 13$

$Barrier7 = \lambda 14 \times Barriers\ to\ a\ low-carbon\ lifestyle + \varepsilon 14$

$Barrier8 = \lambda 15 \times Barriers\ to\ a\ low-carbon\ lifestyle + \varepsilon 15$

Once the loading factors of the measurement model have been estimated, these factors are employed in the construction of the latent variables by assigning a weight to the contributions of each indicator in relation to their respective latent variables. To illustrate, if the loading factor for an indicator is high, it can be concluded that the indicator is a strong representation of the latent variable. In particular, for the latent variable representing, for example, *attitude*,

it is constructed by weighting the indicators *worry* and *contribution* according to their respective loading factors, $\lambda 1$ and $\lambda 2$. This ensures that indicators with a stronger relationship to the latent variable have a greater impact on its construction.

### *3.4 Structural model*

In order to conduct the SEM analyses, various SEM models are estimated. These models incorporate direct influences of attitude, subjective norms, and perceived behavioral control, as well as direct effects of the socioeconomic factors gender, age, and income and interaction terms between the TPB elements and the socioeconomic factors. Including these direct and interaction terms of socioeconomic factors allows for investigating whether the impacts of attitude, subjective norms, and perceived behavioral control on diet, transport, and shopping behavior vary depending on gender, age, and income.

The SEM model without interaction terms is constructed as follows: $Diet = \beta 0 + \beta 1 \times Attitude + \beta 2 \times Subjective\ Norms + \beta 3 \times Perceived\ Behavioral\ Control + \epsilon$. By way of example, diet is used here as the dependent variable.

The SEM model with interaction terms is constructed as follows: $Diet = \beta 0 + \beta 1 \times Attitude + \beta 2 \times Subjective\ Norms + \beta 3 \times Perceived\ Behavioral\ Control + \beta 4 \times Gender + \beta 5 \times Age + \beta 6 \times Income + \beta 7 \times (Attitude \times Gender) + \beta 8 \times (Subjective\ Norms \times Gender) + \beta 9 \times (Perceived\ Behavioral\ Control \times Gender) + \beta 10 \times (Attitude \times Age) + \beta 11 \times (Subjective\ Norms \times Age) + \beta 12 \times (Perceived\ Behavioral\ Control \times Age) + \beta 13 \times (Attitude \times Income) + \beta 14 \times (Subjective\ Norms \times Income) + \beta 15 \times (Perceived\ Behavioral\ Control \times Income) + \epsilon$. This model is used to test the direct and interaction terms of gender, age, and income. Again, by way of example, diet is used here as the dependent variable.

Note that both the SEM models for transport and shopping behavior, with and without interaction terms, are similarly structured, but they have been omitted here for the sake of readability.

### *3.5 Assumptions*

Prior to investigating the hypotheses using structural equation modeling (SEM) analyses, it is important to ensure adherence to the assumptions underlying SEM analyses. If the data do not comply with these assumptions and potential violations are not considered, the analyses may yield erroneous results. As the variables (with the exception of gender) within this study are categorically and ordinally distributed, and SEM originally assumes continuous, multivariate

normally distributed data, it is of great importance to handle this correctly (Finney & DiStefano, 2006). The WLSMV estimator is a method that is well-suited to handling non-normal and ordinal data (Hong et al., 2024). Consequently, this estimator is employed in this study.

Furthermore, the assumptions regarding linearity, multicollinearity and model fit are tested. Additionally, the sample size, the presence of outliers and the handling of missing data are also considered. Given that the data is categorical, the assumption of linearity is adjusted for categorical data using appropriate linking functions (logit/probit). This entails examining the frequency distributions of the variables. It is essential that the distributions of the variables are well distributed across the categories, as this ensures that the logit or probit link functions model appropriate probabilistic relationships. The distributions of the variables in this study are, for the most part, satisfactory. Furthermore, several fit indices are considered. When these indices are within the acceptable limits, it can be concluded that the chosen link functions are a suitable fit to the relationships in the data. In this study, the model fit indices are indicative of a good fit.

Subsequently, the correlations were employed to investigate the potential for multicollinearity. Normally, variance inflation factors (VIF) values are employed for this purpose. However, given the use of latent variables in this study, an alternative approach for these variables was adopted. None of the correlations exceeded the threshold of 0.80 and the VIF values for the observed variables were well below the threshold of 5, indicating that multicollinearity is not a significant concern in this model.

Finally, the sample size, outliers and missing data were verified. The sample size was found to be more than sufficient. The outliers were identified and subjected to further analysis, and there were no missing values in the dataset. Appendix III provides a detailed elaboration of the testing of these assumptions.

### *3.6 Data*

This study utilizes data retrieved from a questionnaire conducted on the social media platform WeChat. WeChat, the most widely utilized social media platform, provides practically everything the average smartphone user desires: users can make calls, send messages, share photos, as well as make payments, play games, and more (Tu, 2016). Given that WeChat is a popular and widely used application, it serves as an appropriate medium for easily reaching a large number of respondents.

The questionnaire was surveyed among a sample of 4000 WeChat users. Among these 4000 users, 334 did not answer one or more of the questions. It is unclear why these questions

were not answered by the respective respondents. Respondents with missing values are excluded from the analyses, resulting in a final dataset of 3666 respondents (91.7%).

### *3.7 Operationalisations and distributions*

To properly understand the possible influencing factors of a low-carbon lifestyle, a precise operationalization of core constructs is needed. This section explains the operationalization of variables attitude, subjective norm, perceived behavioral control, and socioeconomic factors, in addition to the dependent variables diet, transport and shopping behavior, all of which are inherent to a low-carbon lifestyle. This section also focuses on the descriptive statistics of the variables to give an overview of their distribution. Appendix I gives a full overview of the operationalizations and shows the frequency tables of all questions used.

#### *3.7.1 Independent variable 'attitude'*

The latent variable attitude involves assessing how worried a respondent is about the impact of climate change and to what extent they believe personal lifestyle choices can contribute to addressing climate change. To indicate the level of concern, respondents are given four response options ranging from *not at all worried* to *very worried*. Additionally, respondents need to express the extent to which they believe their actions are significant on a scale ranging from a low to a strong belief regarding the contribution of their personal choices in addressing climate change.

Figure 3 shows the distributions of the indicators of attitude. The first indicator shows that the vast majority of respondents are sometimes or often worried about climate change (58.7% and 31.2%, respectively). In addition, regarding the question to what extent respondents think that personal lifestyle choices can contribute to addressing climate change, the answers are fairly distributed, with many respondents selecting either the third (38.0%) or the fourth (33.6%) response category. Additionally, 23.6% of respondents indicate that personal lifestyle choices can make a great difference for climate change. Only a small proportion of respondents reported an extreme attitude, with 0.3% indicating *not at all.* The category *don't know* was selected by 0.4% of respondents.

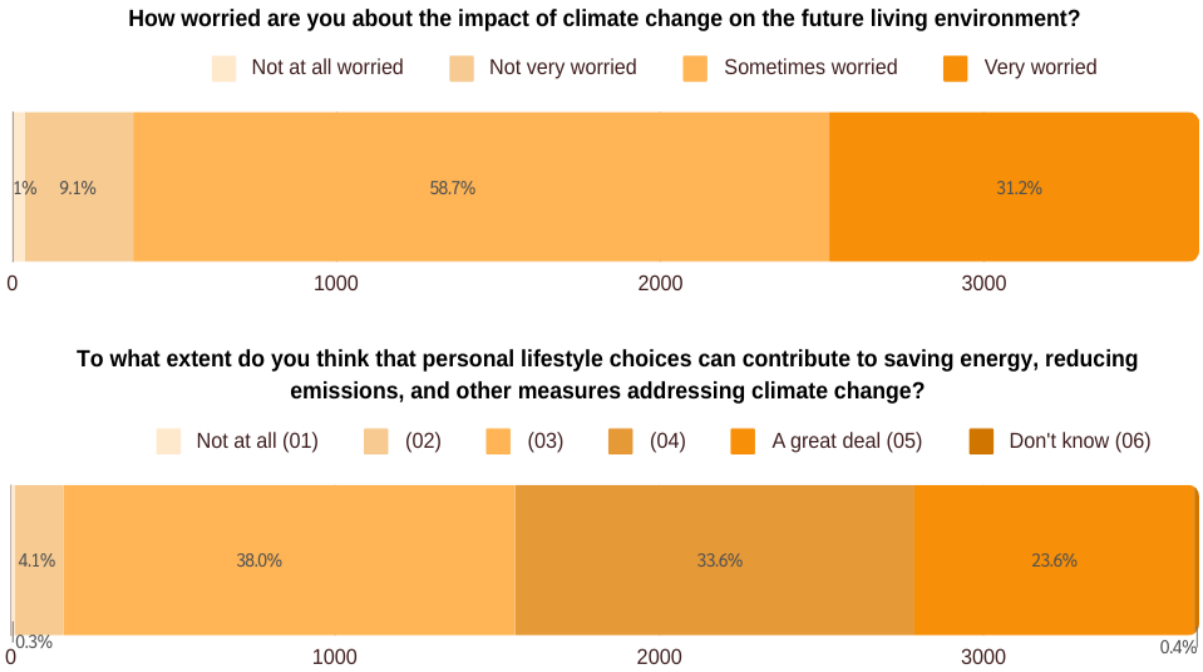


***Figure 3.*** Distribution of the indicators of attitude

*3.7.2 Independent variable 'subjective norms'*

The variable subjective norms is formed by combining the views on a low-carbon lifestyle of close family members and friends. This results in a latent variable that should reflect subjective norms about a low-carbon lifestyle in an individual's close social environment.

Figure 4 shows the distribution of the indicators of subjective norms. Most respondents indicated their close family members support a low-carbon lifestyle, with 47.0% indicating *support* and 46.5% indicating *very supportive*. Only 6.5% reported that their family members *don't care or rarely think about it*, and a negligible one respondent indicated that its family members are *against* it. Similarly, 55.1% of respondents indicated their friends have a *supportive* view, and 29.5% indicated *very supportive* views from friends. A higher proportion respondents (15.2%) compared to family members indicated that friends *don't care or rarely think about it*. Finally, only 0.2%, which is 8 respondents, indicated that friends are *against* a low-carbon lifestyle.

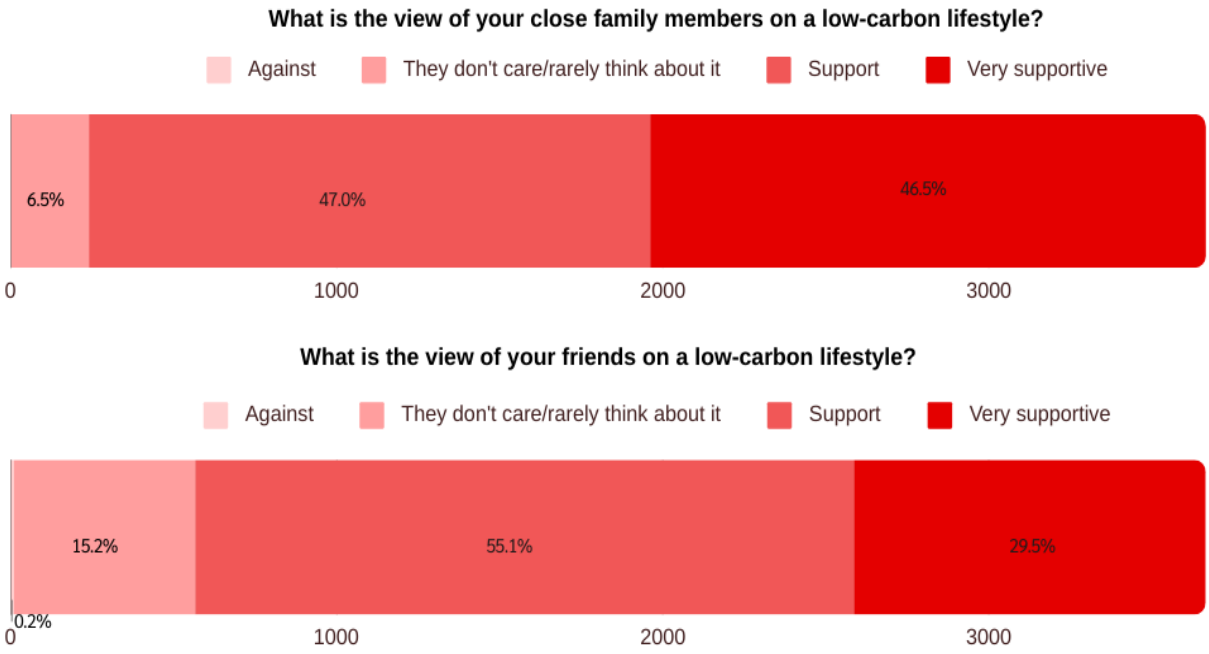


***Figure 4.*** Distribution of the indicators of subjective norms

*3.7.3 Independent variable 'perceived behavioral control'*

Perceived behavioral control is measured by two latent variables: self-reported knowledge levels on sustainability themes and perceived barriers encountered by respondents in adopting a low-carbon lifestyle. This approach was chosen because it was not feasible to create a single latent variable from these indicators due to the significantly different measurement methods of the questions. Combining the rating of potential barriers with the knowledge level into one latent variable was attempted and tested in the model, but it did not adequately represent the concept of 'perceived behavioral control.' Therefore, it was decided to construct two separate latent variables. This way, the two variables together can provide a good representation of the respondents' knowledge regarding the impact of different facets of behavior, despite any obstacles they may face.

Figure 5 presents the distribution of the indicators of barriers to a low-carbon lifestyle. When considering the perceived barriers, it is noteworthy that 20.7% of respondents cite the higher cost of low-carbon alternatives as the main reason for not adopting them. Additionally, the absence of adequate infrastructure and supportive policies is perceived as a significant barrier by many respondents (4 stars: 27.8%; 5 stars: 15.8%). More than half of the respondents rate the barrier *I don't see why we need a low-carbon lifestyle* with 1 star, indicating that at least half of the respondents recognize the necessity of a low-carbon lifestyle.

Figure 6 presents the distribution of the indicators of knowledge of climate impact. When examining the respondents' knowledge level regarding the impact of diet, transport and shopping behavior, it is notable that most respondents report having moderate to good knowledge about these aspects. The largest group of respondents has great self-reported knowledge about the impact of transport (71.7%). In addition, 43.3% of respondents have moderate to good knowledge about the impact of shopping behavior and 36% have knowledge about the impact of diet.

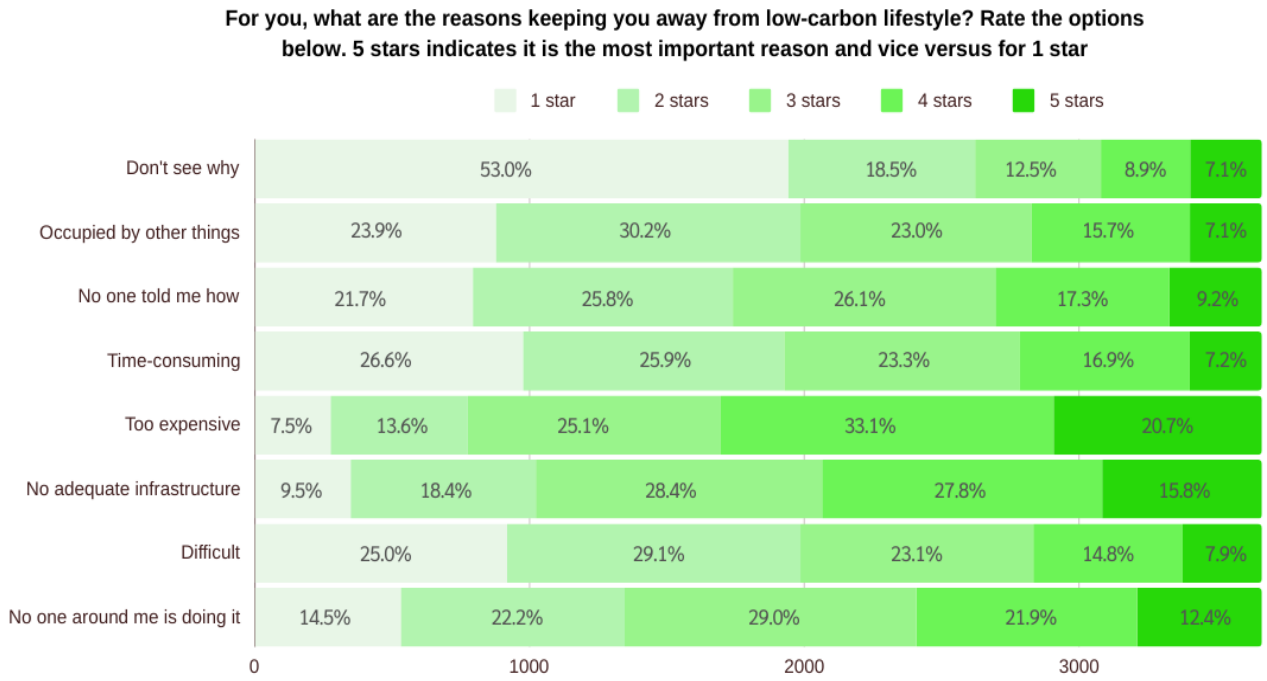


***Figure 5.*** Distribution of the indicators of barriers to a low-carbon lifestyle

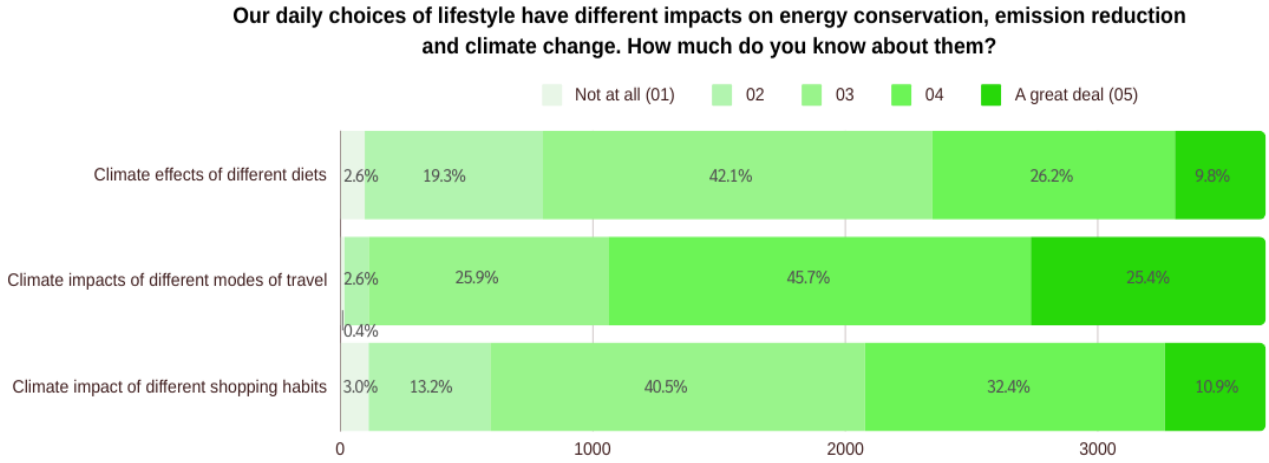


***Figure 6.*** Distribution of the indicators of knowledge of climate impact

*3.7.4 Independent variables socioeconomic factors*

Gender, age, and income constitute the socioeconomic factors considered in this study. Figures 7, 8, and 9 present the frequencies and percentages for these factors. Further details on the frequencies and percentages can be found in Appendix II. All three variables are categorical, with gender measured on a nominal, dichotomous scale, and age and income on ordinal scales. Furthermore, it is important to note that in this study, the gender variable is coded as 1 = male and 2 = female, which differs from the more common binary coding of 0 = male and 1 = female. Despite this discrepancy, the variable is treated as a binary exogenous variable in the SEM analysis, in line with the guidelines of the lavaan package (*lavaan.org - Categorical Data*, n.d.). This approach ensures that the methodology is sound and that the results are valid.

Descriptive analyses indicate that the group of respondents in this study is representative of a large portion of the Chinese population. The gender distribution is nearly equal, with 49.8% male and 50.2% female respondents. The age distribution of respondents shows an even spread across categories, with the highest percentages in the 18-30 years old (25.6%) and 41-50 years old (25.1%) groups. The smallest category is those over 60 years old (3.8%).

Furthermore, income levels among respondents vary, with the largest group earning between 4500 and 8000 RMB monthly per head (34.6%). Smaller percentages of the sample fall into lower income brackets, such as less than 400 RMB (2.4%) and 400-900 RMB (1.5%). In most categories, there is a sufficient number of respondents to represent the majority of the Chinese population.

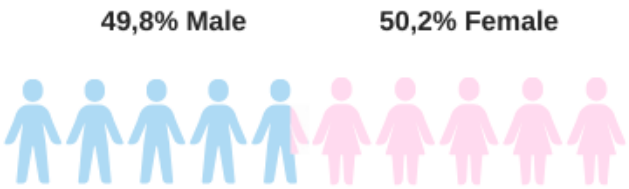


***Figure 7.*** Distribution of the socioeconomic factor *gender*

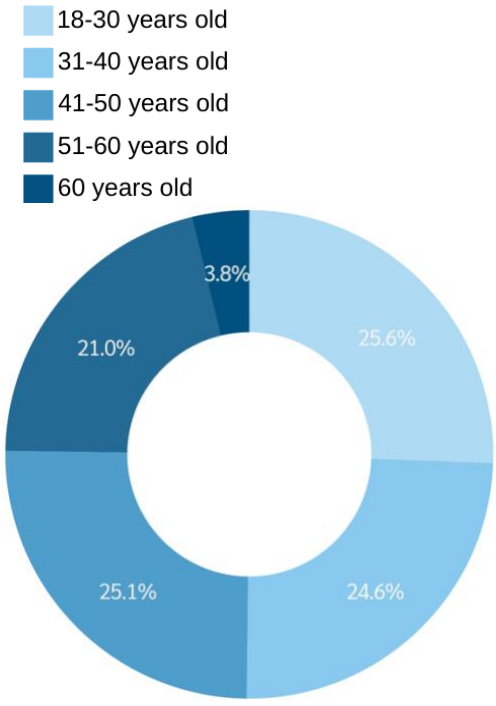


***Figure 8.*** Distribution of the socioeconomic factor *age*

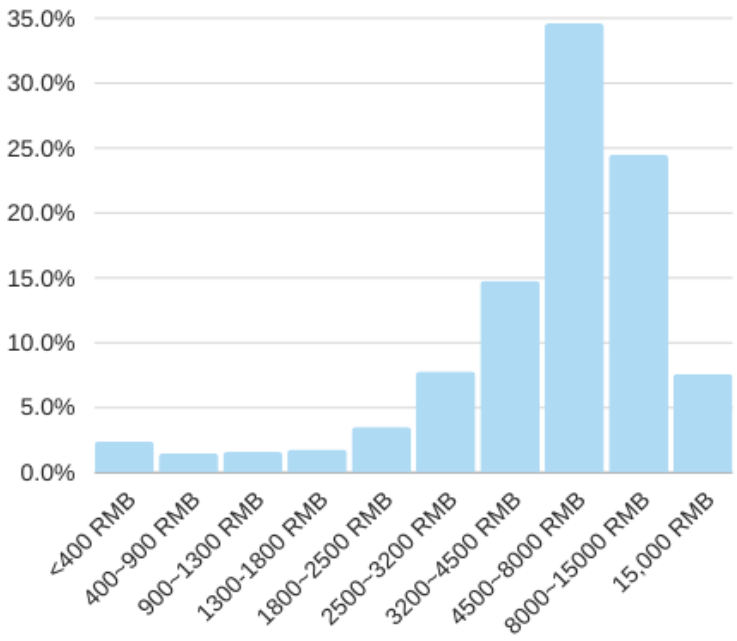


***Figure 9.*** Distribution of the socioeconomic factor *income*

*3.7.5 Dependent variables*

The dependent variables inherent to a low-carbon lifestyle—diet, transport, and shopping behavior—are operationalized by querying the extent to which respondents consider environmental impacts in their daily decisions regarding these three areas.

Figure 10 presents the distribution of responses for these dependent variables on a five-point scale ranging from 'never' to 'often'. The frequency distribution for considering the environmental impact of diet choices shows that nearly half of the respondents (47.1%) indicated that they *sometimes* consider environmental impact, with a substantial portion (25.2%) indicating *often*. A smaller percentage reported considering it *in a small number of cases* (18.0%), *rarely* (7.7%), or *never* (2.0%).

For transport choices, a significant majority of respondents (50.2%) reported *often* considering the environmental impact. Another large group (39.5%) reported *sometimes*, with smaller percentages for *in a small number of cases* (8.0%), *rarely* (1.9%), and *never* (0.3%).

Regarding shopping behavior, 42.1% of respondents indicated that they *sometimes* consider the environmental impact, followed by 24.7% who indicated *often*. The responses also included *in a small number of cases* (21.0%), *rarely* (9.4%), and *never* (2.8%)

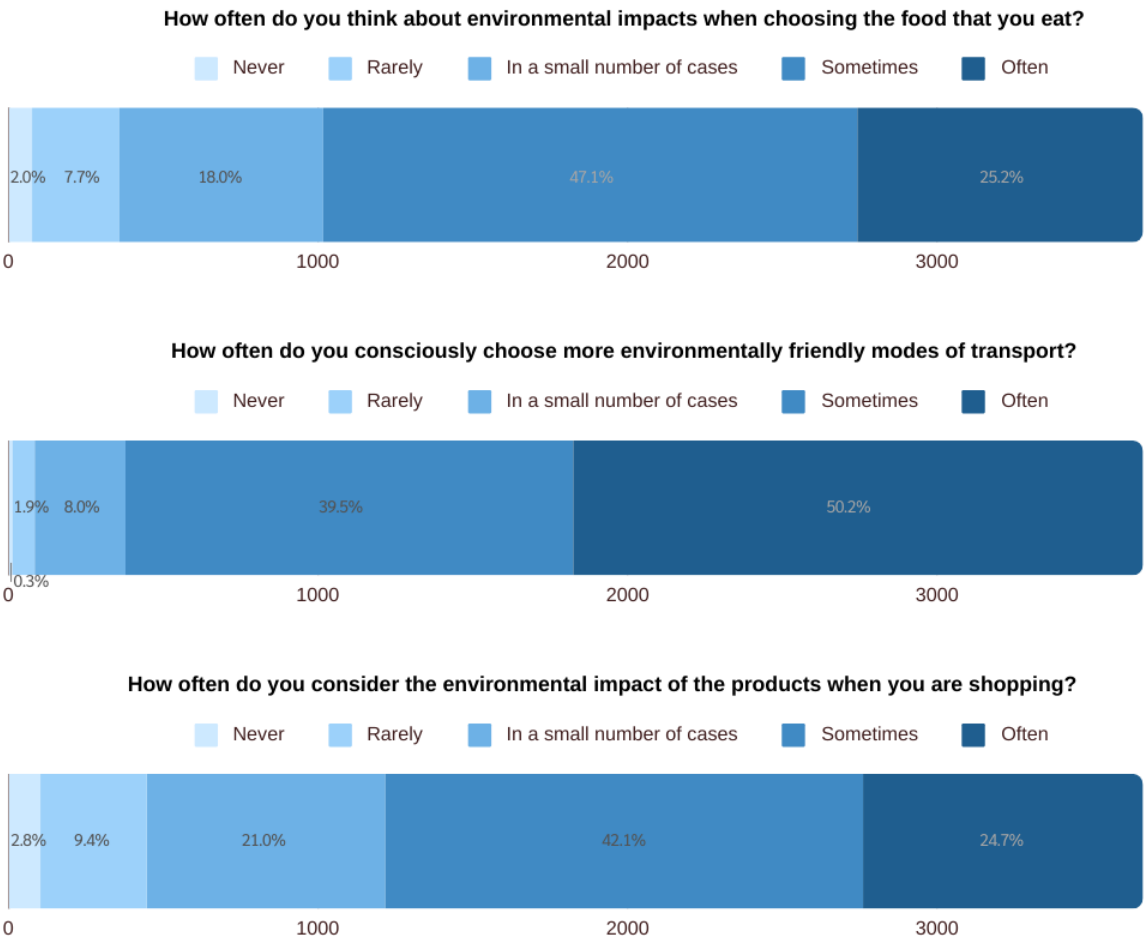


***Figure 10.*** Distribution of the dependent variables diet, transport, and shopping behavior

*3.8 Model fit and evaluation*

*3.8.1 Model fit of the model without interaction terms*

Since a good fit of the model is essential for obtaining the corrects effects of variables within an SEM analysis, the model fit is first evaluated using different measures. Table 2 shows all fit indices for the SEM model without interaction terms.

To begin with, the chi-square test score is considered. In this case, the chi-square test for model fit shows a significant result: $\chi^2$ (109) = 779.876, $p < 0.001$. This result indicates a significant difference between the fit of the specified model and the fit of the observed data. However, it is important to note that the chi-square statistic is often significant in large samples, and since this study also uses a large sample (n = 3666), additional fit indices are used to fully correctly assess the model fit.

The comparative fit index (CFI) also compares the fit of the user-specified model to a baseline model. The CFI values for the model without interaction terms are 0.993 for the standardized version and 0.981 for the scaled version. Values closer to 1.0 indicate a good fit,

and generally, models with a CFI above 0.90 are considered a good fit. Therefore, these values suggest that the model fits the data very well.

Similarly, the Tucker-Lewis index (TLI), which also assesses model fit by comparing user-specified model to a baseline model, shows values of 0.991 (standardized) and 0.974 (scaled). Like the CFI, TLI values closer to 1.0 indicate a better fit, with values above 0.90 generally seen as satisfactory. The high TLI values in this model further confirm that it fits the data very well.

Another important measure is the root mean square error of approximation (RMSEA). This measure evaluates how well the model, with unknown but optimal parameter estimates, fits the population's covariance matrix. For this model, the RMSEA is 0.034 for the standardized version and 0.041 for the scaled version. As an RMSEA value less than 0.06 indicates a close fit, this fit measure also shows a close fit to the data.

Additionally, the standardized root mean square residual (SRMR) value is 0.031. An SRMR value less than 0.08 is generally considered as a good fit, which indicates that the model's residuals are small and that the predicted and observed matrices match well.

In short, the fit indices all indicate that the SEM model without interaction terms provides a robust representation of the relationships between the TPB elements and the aspects of a low-carbon lifestyle.

*Table 2: Fit indices for the SEM model without interaction terms*

| **Fit index** | **Value (standardized)** | **Value (scaled)** |
|---|---|---|
| Chi-square test of model fit | 558.981 | 779.876 |
| Degrees of freedom | 109 | 109 |
| Comparative fit index (CFI) | 0.993 | 0.981 |
| Tucker-Lewis index (TLI) | 0.991 | 0.974 |
| Root mean square error of approximation (RMSEA) | 0.034 | 0.041 |
| Standardized root mean square residual (SRMR) | 0.031 | 0.031 |

### *3.8.2 Modification indices*

In order to achieve a good model fit, modification indices were also considered during the SEM analyses. The modification indices indicate which additional parameters could enhance the model fit if incorporated into the model (Iacobucci, 2009). Based on these indices, 7 covariances were incorporated into both SEM models, which are both statistically significant and theoretically relevant. The added covariances are described and explained in detail in section 4.4.1 of the results. These covariances contribute to the explanation of residual correlations that were not originally included in the model, thereby improving the model fit.

*3.8.3 Model fit of the model with interaction terms*

Table 3 shows all fit indices for the SEM model with interaction terms. The chi-square test of model fit for the SEM model with interaction terms has a value of 1281.135 (standardized) and 960.088 (scaled) with 334 degrees of freedom. This significant chi-square test value suggests that the model does not perfectly fit the data, but as pointed out before, this is common in large samples because of the sensitivity of the chi-square test. The comparative fit index (CFI) values are 0.984 (standardized) and 0.979 (scaled). As values close to 1.0 are considered to be good, both values indicate a very good fit.

The Tucker-Lewis index (TLI) values are 0.992 (standardized) and 0.989 (scaled), which again suggests that the model fits the data very well, given that TLI values above 0.90 are considered as a good fit. The root mean square error of approximation (RMSEA) values are 0.031 (standardized) and 0.026 (scaled). Both the standardized and scaled RMSEA indicate a close fit (values below 0.05). Lastly, the standardized root mean square residual (SRMR) is 0.030 for both standardized and scaled, suggesting a good fit as well, as values below 0.08 are generally considered acceptable.

In conclusion, the fit indices for the SEM models, both without and with interaction terms, have a good overall fit. The model without interaction terms has a CFI value of 0.981 and a TLI of 0.974, while the model with interaction terms shows a CFI of 0.982 and a TLI of 0.992. Additionally, the RMSEA is slightly lower for the model with interaction terms (0.028 standardized and 0.023 scaled) compared to the model without interaction terms (0.034 standardized and 0.041 scaled). Both models have comparable SRMR values of 0.031 and 0.029, respectively.

These results suggest that the inclusion of interaction terms marginally improves the model fit, as evidenced by the slightly better fit indices. Regardless, both models have good scores on the fit indices, indicating a very good fit. It can thus be concluded that the addition of interaction terms can provide an understanding of the influences of key variables within a demographic context without degrading the model fit.

*Table 3: Fit indices for the SEM model with interaction terms*

| **Fit index** | **Value (standardized)** | **Value (scaled)** |
|---|---|---|
| Chi-square test of model fit | 1281.135 | 960.088 |
| Degrees of freedom | 334 | 334 |
| Comparative fit index (CFI) | 0.986 | 0.982 |
| Tucker-Lewis index (TLI) | 0.993 | 0.992 |
| Root mean square error of approximation (RMSEA) | 0.028 | 0.023 |
| Standardized root mean square residual (SRMR) | 0.029 | 0.029 |

## 4. Results

This paragraph discusses the results of the analyses performed. The first part addresses the interrelationships of the variables, while the second part discusses the structural equation models and the corresponding conclusions from these analyses. Here, both the results of the SEM analysis without and with the socioeconomic interaction terms are discussed and compared.

### *4.1 Correlations*

The examination of correlations can provide insight into the relationship between variables. This insight is important when testing hypotheses within SEM, given that SEM is based on assumptions about the relationships between variables. Thus, understanding which variables correlate positively or negatively can assist in the comprehension of the model. Table 4 presents the correlations between the variables of the model. Values range from 1 to -1 with a value of 1 indicating a perfect positive monotonic relationship, −1 indicating a perfect negative monotonic relationship and 0 indicating no monotonic relationship. The correlations between two observed variables or between one observed and one latent variable are calculated using Spearman's rank correlation. The correlations between two latent variables are deducted from the standardized solution. The standardized solution provides correlations based on the structural equation model, which ensures that this correlation also considers the measurement error and the relationships specified in the model.

To begin with, the various aspects of a low-carbon lifestyle, namely diet, transport and shopping behavior, exhibit a positive correlation with one another. These correlations indicate that individuals who exhibit low-carbon behavior in one aspect are prone to exhibiting low-carbon behavior in other aspects as well.

Additionally, the aspects of a low-carbon lifestyle are all positively correlated with attitude, subjective norms, and knowledge of climate impact. For instance, diet shows strong positive correlations with subjective norms ($r = .614$, $p < .001$) and knowledge of climate impact ($r = .577$, $p < .001$), indicating that individuals who have a low-carbon diet, perceive more social support and have greater knowledge of climate impact. Similarly, shopping behavior is positively correlated with subjective norms ($r = .610$, $p < .001$) and knowledge of climate impact ($r = .617$, $p < .001$), which reinforces the importance of the influence of one's social environment and knowledge of climate impact regarding their adoption of low-carbon shopping behavior. Furthermore, all aspects of a low-carbon lifestyle demonstrate a negative

correlation with barriers to a low-carbon lifestyle. It is important to acknowledge, however, that for this variable, an increase in value corresponds with a greater prevalence of barriers. For instance, there is a negative correlation between barriers to a low-carbon lifestyle and shopping behavior ($r = -.352$, $p < .001$). This implies that individuals who do not engage in low-carbon shopping behavior encounter more or greater barriers to a low-carbon lifestyle.

Moreover, the correlation between attitude and subjective norms ($r = .550$, $p < .001$) is high, indicating a strong positive relationship. This suggests that individuals who have a positive attitude towards a low-carbon lifestyle are likely influenced by the social pressure they experience from close family and friends. Similarly, the correlation between attitude and knowledge of climate impact ($r = .516$, $p < .001$) highlights that individuals with a positive attitude towards a low-carbon lifestyle tend to have more knowledge of climate impact.

In addition, the correlation between subjective norms and knowledge of climate impact ($r = .489$, $p < .001$) is also large, suggesting that social pressure plays an important role in the improvement of an individuals' knowledge of climate impact. This is consistent with the TPB framework, which states that subjective norms and attitude together partially shape an individuals' intentions and behaviors.

Furthermore, barriers to low-carbon lifestyle show negative correlations with attitude ($r = -.430$, $p < .001$), subjective norms ($r = -.441$, $p < .001$), and knowledge of climate impact ($r = -.314$, $p < .001$). These negative correlations indicate that perceived barriers are significant obstacles to adopting a positive attitude, feeling social pressure, and acquiring knowledge about a low-carbon lifestyle.

Finally, when socioeconomic variables are considered, it can be noted that income shows positive correlations with attitude ($r = .148$, $p < .001$), subjective norms ($r = .096$, $p < .01$), and knowledge of climate impact ($r = .153$, $p < .001$). This indicates that higher income individuals are more likely to have positive attitudes, experience more social pressure and have more knowledge of climate impact. In contrast, age has negative correlations with these three elements, suggesting that older individuals have slightly less positive attitudes towards a low-carbon lifestyle ($r = -.098$, $p < .001$), are less sensitive to subjective norms ($r = -.046$, $p < .001$), and have less knowledge of climate impact ($r = -.093$, $p < .001$). Further, the positive correlation of age with barriers to a low-carbon lifestyle ($r = .083$, $p < .001$) indicates that older individuals encounter more barriers when adopting a low-carbon lifestyle. Although these correlation coefficients are relatively weak, they do indicate a significant effect. In addition, gender shows negative correlations with attitude ($r = -.070$, $p < 0.01$) and subjective norms ($r = -.046$, $p <$

0.01) but a positive correlation with barriers to a low-carbon lifestyle ($r = .076$, $p < 0.001$). This indicates that males generally have slightly less positive attitudes towards a low-carbon lifestyle, experience less social pressure from their environment and experience more or greater barriers to adopting a low-carbon lifestyle than females.

Overall, the correlations show that there is a strong interconnectedness among the TPB elements and that socioeconomic factors are also important when considering the effect of these aspects on low-carbon lifestyles. As high intercorrelations have the potential to give rise to multicollinearity problems, the Variance Inflation Factor (VIF) values for the observable predictors, correlations, model fit, and model specification were evaluated prior to conducting the SEM analyses. As previously stated, the model fit indices are satisfactory, and multicollinearity does not appear to be a significant issue. Appendix III provides a detailed elaboration of the testing of these and other assumptions. In addition, the high correlations are consistent with previous research and the TPB framework, which states that attitudes, subjective norms and PBC are interrelated constructs that collectively influence behavior (Ajzen, 1991; Armitage & Conner, 2001).

*Table 4. Correlation matrix*

| ***Variable*** | ***1*** | ***2*** | ***3*** | ***4*** | ***5*** | ***6*** | ***7*** | ***8*** | ***9*** | **10** |
|---|---|---|---|---|---|---|---|---|---|---|
| **1. Attitude** | - | | | | | | | | | |
| **2. Subjective norms** | .550*** | - | | | | | | | | |
| **3. Knowledge of climate impact** | .516*** | .489*** | - | | | | | | | |
| **4. Barriers to low-carbon lifestyle** | -.430*** | -.441*** | -.314*** | - | | | | | | |
| **5. Diet** | .469*** | .614*** | .577*** | -.356*** | - | | | | | |
| **6. Transport** | .468*** | .547*** | .413*** | -.335*** | .427*** | - | | | | |
| **7. Shopping behavior** | .457*** | .610*** | .617*** | -.352*** | .527*** | .372*** | - | | | |
| **8. Gender** | -.070** | -.046** | -.022 | .076*** | .025 | .004 | -.004 | - | | |
| **9. Age** | -.098*** | -.046** | -.093*** | .083*** | .043** | .083*** | .016 | .262*** | - | |
| **10. Income** | .148*** | .096*** | .153*** | -.114*** | .057*** | -.008 | .096*** | .107*** | -.155*** | - |

**Note**: ***: $p < 0.001$, **: $p < 0.01$, *: $p < 0.05$

*4.2 SEM analysis without interaction terms*

Table 5 presents the results of the structural equation modeling (SEM) analysis conducted without considering interaction terms. This table illustrates the effects of the TPB elements on three aspects of a low-carbon lifestyle: diet, transport, and shopping behavior. The estimates, standard errors, z-values, p-values, and standardized variable estimates provide a detailed overview of the relationships between these variables.

For a low-carbon diet, attitude shows a negative association (estimate = -0.029, p = 0.532) which is not significant. Thus, no conclusions can be drawn from this. Conversely, subjective norms (estimate = 0.447, p < 0.001) and knowledge of climate impact (estimate = 0.498, p < 0.001) both exhibit strong positive and significant associations, suggesting that social pressure and knowledge of climate impact positively influence a low-carbon diet. Barriers to low-carbon lifestyle negatively impact a low-carbon diet (estimate = -0.168, p < 0.001), which highlights the inhibitory role of perceived barriers.

Regarding low-carbon transport, attitude (estimate = 0.209, p < 0.001) and subjective norms (estimate = 0.394, p < 0.001) have a positive influence. This indicates that favorable attitudes and social expectations are critical drivers of choosing low-carbon transport. Knowledge of climate impact (estimate = 0.227, p < 0.001) also positively affects low-carbon transport, while barriers present a significant negative influence (estimate = -0.177, p < 0.001).

When examining the influences of shopping behavior, it becomes evident that attitude (estimate = -0.102, p = 0.037) negatively affects low-carbon shopping choices, which clearly contrasts with the effect of attitude on low-carbon transport. A potential explanation for this contrast is discussed in the conclusion and discussion paragraph. Furthermore, subjective norms (estimate = 0.403, p < 0.001) and knowledge of climate impact (estimate = 0.755, p < 0.001) do exert strong positive influences on low-carbon shopping behavior. Barriers, again, negatively impact low-carbon shopping behavior (estimate = -0.151, p < 0.001).

*Table 5: Results SEM analysis without interaction terms*

| Path | Estimate | Std. Err | z-value | P(>\|z\|) | Std. all. |
|---|---|---|---|---|---|
| Diet ~ Attitude | -0.029 | 0.047 | -0.625 | 0.532 | -0.019 |
| Diet ~ Subjective norms | 0.447 | 0.032 | 13.982 | 0.000 | 0.378 |
| Diet ~ Knowledge of climate impact | 0.498 | 0.059 | 8.513 | 0.000 | 0.258 |
| Diet ~ Barriers to low-carbon lifestyle | -0.168 | 0.033 | -5.146 | 0.000 | -0.101 |
| Transport ~ Attitude | 0.209 | 0.051 | 4.092 | 0.000 | 0.135 |
| Transport ~ Subjective norms | 0.394 | 0.036 | 10.917 | 0.000 | 0.333 |
| Transport ~ Knowledge of climate impact | 0.227 | 0.057 | 3.960 | 0.000 | 0.118 |
| Transport ~ Barriers to low-carbon lifestyle | -0.177 | 0.037 | -4.764 | 0.000 | -0.106 |
| Shopping behavior ~ Attitude | -0.102 | 0.049 | -2.086 | 0.037 | -0.066 |
| Shopping behavior ~ Subjective norms | 0.403 | 0.032 | 12.700 | 0.000 | 0.340 |
| Shopping behavior ~ Knowledge of climate impact | 0.755 | 0.059 | 12.726 | 0.000 | 0.391 |
| Shopping behavior ~ Barriers to low-carbon lifestyle | -0.151 | 0.032 | -4.645 | 0.000 | -0.091 |

### *4.3 SEM analysis with interaction terms*

Table 6 presents the results of the SEM analysis conducted while considering the direct effects and the interaction terms of variables gender, age, and income. To represent the interaction

effect between two variables, for instance income and attitude on diet, the notation 'Diet ~ Income#Attitude' is used. Compared to table 5, table 6 has an additional column: the standardized latent variable estimates (Std. lv). As the model with interaction terms also includes directly observable indicators, the standardized latent variable estimates sometimes differ slightly from the fully standardized estimates. To give a comprehensive understanding, both are shown in the table.

Additionally, figure 11 shows the separate path diagrams for diet, transport, and shopping behavior with the corresponding significant weights at a significance level of 0.05 or lower. In displaying the interaction terms, ⚥ stands for *gender*, 👪 for *age*, and 💵 for *income*.

*4.3.1 SEM analysis of diet*

To begin with, the direct effects of socioeconomic factors indicate that income has a significant positive effect on the adoption of a low-carbon diet. This implies that individuals with higher incomes are more likely to adopt a low-carbon diet. The other direct effects of gender and age are not statistically significant at the $p < 0.05$ level.

When considering the effects of TPB elements on a low-carbon diet, it is notable that subjective norms (estimate = 0.426, $p < 0.001$) and knowledge about climate impact (estimate = 0.563, $p < 0.001$) also show a significant positive influence in the model with interactions. In addition, barriers to a low-carbon lifestyle (estimate = -0.187, $p < 0.001$) again show a negative significant influence.

Moreover, the interaction terms between attitude and gender (estimate = 0.125, $p = 0.036$) and attitude and age (estimate = 0.086, $p = 0.001$) show small but significant positive effects on a low-carbon diet. This suggests that males and older people with positive attitudes towards a low-carbon lifestyle are more likely to adopt a low-carbon diet, as females are coded 1, and males are coded 2 in this study. Thus, the effect of attitude on diet is conditional on the gender and age. Whereas for females and younger people there seems to be less or even no effect, for males and older people there could be an effect of attitude on a low-carbon diet. It is important to highlight that the interaction effect with gender exhibits a distinct effect from that observed in previous studies. In fact, several previous studies have indicated that females tend to hold more positive attitudes towards a low-carbon diet (Ritzel & Mann, 2021; Widegren & Sand, 2021). Potential explanations for these discrepancies are discussed in the conclusion and discussion paragraph.

Additionally, the negative interaction term between gender and barriers to a low-carbon lifestyle (estimate = -0.065, p = 0.028) shows that the influence of perceived barriers on a low-carbon diet is greater for males than for females. This finding is consistent with previous research indicating that males do experience greater barriers than females in making sustainable food choices (Gifford & Chen, 2017).

*4.3.2 SEM analysis of transport*

Furthermore, when looking at low-carbon transport, it can be noted that the results of the non-interaction model are mirrored: attitude, subjective norms and knowledge about climate impact have a positive significant influence and barriers to low-carbon lifestyle has a negative significant influence on the adoption of low-carbon transport.

Moreover, the interaction terms show that the interaction of attitude with gender (estimate = 0.178, p = 0.004) has a positive influence on low-carbon transport behavior, indicating that males with more positive attitudes towards a low-carbon lifestyle are more likely to adopt to low-carbon transport. In addition, the interactions show a positive effect of age on climate impact knowledge (estimate = 0.071, p = 0.001) and a negative effect of income on climate impact knowledge (estimate = -0.030, p = 0.004). This indicates that knowledge of climate impact for older individuals has a greater influence on low-carbon transport than younger individuals. On the other hand, knowledge of climate impact for individuals with more income has a smaller influence on low-carbon transport than for individuals with less income. As this latter effect is not consistent with the predominant findings of previous studies, it is important to highlight this discrepancy (Franzen & Vogl, 2013; Otto et al., 2016). A potential explanation for this difference is outlined in the conclusion and discussion paragraph, as previously described.

Finally, the direct effects of gender, age, income, and other interaction terms with these socioeconomic factors are not statistically significant at the $p < 0.05$ level.

*4.3.3 SEM analysis of shopping behavior*

Lastly, regarding low-carbon shopping behavior, subjective norms and knowledge of climate impact are again significant predictors, consistent with the non-interaction model. Further, barriers to a low-carbon lifestyle again exert a negative significant influence on the low-carbon behavior.

In addition, the interaction terms show various significant effects of the socioeconomic factors. To begin with, the interaction of attitude and gender (estimate = 0.172, p = 0.003) has

a positive influence on low-carbon shopping behavior, indicating that attitudes have a stronger influence on low-carbon shopping behaviour for males than for females.

Secondly, the interaction of subjective norms with age (estimate = -0.052, p = 0.031) and income (estimate = 0.033, p = 0.022) shows that the influence of subjective norms on shopping behavior decreases with age but increases with income. In other words, according to this effect, younger individuals and higher income individuals are more sensitive to the influence of subjective norms on their shopping behavior than older individuals and individuals with less income.

Finally, the interaction of knowledge of climate impact (PBC) with age (estimate = 0.049, p = 0.018) and gender (estimate = 0.097, p = 0.045) shows that the influence of knowledge about climate impact on shopping behavior increases with age and that this effect is stronger for males than for females. In other words, older individuals and males are more influenced by their knowledge about climate impact in their shopping behavior than younger individuals and females.

In summary, including interaction terms in the SEM analysis provides more insight into how socioeconomic factors modulate the relationships identified in the non-interaction model. The TPB elements consistently influence low-carbon diet, transport, and shopping behavior. However, the interaction terms reveal that these influences are not uniform across different demographic groups. For instance, while knowledge of climate impact positively influences all three behaviors in the non-interaction model, their impact varies when considering gender, age, and income, as seen in the interaction model. In addition, attitude has no significant effect on the aspects of a low-carbon lifestyle in the non-interaction model but when socioeconomic factors are included, it appears that for certain demographic groups (males, older individuals) it could indeed exert an effect.

### *4.4 Covariances*

In addition to the direct effects of the TPB elements, the SEM model shows different significant covariances between the latent variables and also between their indicators. Appendix IIII provides a comprehensive overview of the covariances. Covariances represent the unstandardized relationships between variables and can therefore be beneficial in comprehending the absolute size of the relationships and their contribution to the overall variance in the model. For instance, the covariance between attitude and subjective norms is notably strong (estimate = 0.300, p < 0.001), which suggests that individuals with positive

attitudes towards a low-carbon lifestyle are more likely to experience strong social pressure to adopt a low-carbon lifestyle.

Additionally, attitude has a significant positive covariance with knowledge of climate impact (estimate = 0.162, $p < 0.001$), which indicates that those with a favorable attitude towards a low-carbon lifestyle, are more likely to have greater knowledge of climate impact. On the other hand, attitude has a significant negative covariance with barriers to low-carbon lifestyle (estimate = -0.162, $p < 0.001$), which suggests a logical relation: that higher perceived barriers are associated with less positive attitudes towards adopting a low-carbon lifestyle.

Similarly, subjective norms and knowledge of climate impact have a positively covariance (estimate = 0.207, $p < 0.001$) and subjective norms and barriers to low-carbon lifestyle a negative covariance (estimate = -0.223, $p < 0.001$). This confirms the notion that an individual's environment and knowledge are essential in overcoming barriers to adopting a low-carbon lifestyle.

Furthermore, knowledge of climate impact has a negative covariance with barriers to low-carbon lifestyle (estimate = -0.092, $p < 0.001$), which indicates that greater knowledge of climate impact is associated with fewer perceived barriers to adopt aspects of a low-carbon lifestyle.

### *4.4.1 Covariances of the indicators of the latent constructs*

An examination of the covariances of the indicators of the latent constructs reveals a significant positive covariance between attitude and knowledge of transport (estimate = 0.134, $p < 0.001$). This indicates that individuals with favorable attitudes towards low-carbon lifestyles are more likely to possess greater knowledge of transport.

Furthermore, there is a negative covariance between the indicator of attitude, 'contribution', and one of the barriers (estimate = -0.205, $p < 0.001$),. This indicates that as the idea that personal choices matter for climate change increases, the perceived barriers decrease.

Additionally, a considerable number of the barriers exhibit positive covariances with one another. This indicates that as one barrier increases, another barrier also tends to increase.

Finally, the knowledge indicators, namely knowledge of diet, knowledge of transport and knowledge of shopping behavior, demonstrate a significant positive covariance with the dependent variables – diet, transport and shopping behavior, respectively. This implies that as knowledge of the impact of a low-carbon aspect increases, the corresponding low-carbon behavior also increases.

*4.4.2 Conclusion regarding the covariances*

In summary, it can be concluded that subjective norms and knowledge about climate impact play a major positive role in promoting low-carbon lifestyles. Additionally, perceived barriers show a negative impact on all three aspects of a low-carbon lifestyle. It is therefore important to consider the barriers that individuals experience while adopting to a low-carbon lifestyle. Finally, the covariances of the latent construct indicators show that positive attitudes and beliefs about the effectiveness of personal choices can reduce perceived barriers, while knowledge is directly linked to performing low-carbon behavior. Furthermore, the results demonstrate that barriers often show covariance, suggesting that addressing multiple barriers instead of focusing on one, may be an effective approach.

Thus, in addition to the previously identified correlations, these covariances provide a comprehensive representation of the interrelationships between variables, encompassing both absolute changes (covariances) and standardized effects (correlations).

*Table 6: Results SEM analysis with interaction terms*

| Path | Estimate | Std. Err | z-value | P(>\|z\|) | Std. lv | Std. all |
|---|---|---|---|---|---|---|
| Diet ~ Attitude | -0.020 | 0.045 | -0.433 | 0.665 | -0.012 | -0.012 |
| Diet ~ Subjective norms | 0.426 | 0.030 | 14.101 | 0.000 | 0.365 | 0.361 |
| Diet ~ Knowledge of climate impact | 0.563 | 0.061 | 9.279 | 0.000 | 0.278 | 0.275 |
| Diet ~ Barriers to low carbon lifestyle | -0.187 | 0.032 | -5.759 | 0.000 | -0.110 | -0.109 |
| Diet ~ Gender | -0.100 | 0.270 | -0.370 | 0.711 | -0.100 | -0.050 |
| Diet ~ Age | 0.132 | 0.114 | 1.157 | 0.247 | 0.132 | 0.155 |
| Diet ~ Income | 0.120 | 0.059 | 2.039 | 0.041 | 0.120 | 0.223 |
| Diet ~ Gender#Attitude | 0.125 | 0.060 | 2.096 | 0.036 | 0.125 | 0.039 |
| Diet ~ Age#Attitude | 0.086 | 0.025 | 3.443 | 0.001 | 0.086 | 0.065 |
| Diet ~ Income#Attitude | 0.007 | 0.014 | 0.516 | 0.606 | 0.007 | 0.009 |
| Diet ~ Gender#Subjective norms | 0.011 | 0.057 | 0.201 | 0.841 | 0.011 | 0.020 |
| Diet ~ Age#Subjective norms | -0.023 | 0.024 | -0.931 | 0.352 | -0.023 | -0.092 |
| Diet ~ Income#Subjective norms | -0.004 | 0.014 | -0.263 | 0.792 | -0.004 | -0.024 |
| Diet ~ Gender#Knowledge of climate impact | 0.051 | 0.049 | 1.049 | 0.294 | 0.051 | 0.101 |
| Diet ~ Age#Knowledge of climate impact | 0.002 | 0.021 | 0.114 | 0.909 | 0.002 | 0.011 |
| Diet ~ Income#Knowledge of climate impact | -0.014 | 0.010 | -1.324 | 0.185 | -0.014 | -0.099 |
| Diet ~ Gender#Barriers to low carbon lifestyle | -0.065 | 0.030 | -2.191 | 0.028 | -0.065 | -0.076 |
| Diet ~ Age#Barriers to low carbon lifestyle | -0.008 | 0.012 | -0.701 | 0.483 | -0.008 | -0.024 |
| Diet ~ Income#Barriers to low carbon lifestyle | -0.009 | 0.007 | -1.329 | 0.184 | -0.009 | -0.042 |
| Transport ~ Attitude | 0.249 | 0.049 | 5.053 | 0.000 | 0.159 | 0.157 |
| Transport ~ Subjective norms | 0.376 | 0.034 | 11.098 | 0.000 | 0.322 | 0.318 |
| Transport ~ Knowledge of climate impact | 0.227 | 0.057 | 3.962 | 0.000 | 0.112 | 0.111 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Transport ~ Barriers to low carbon lifestyle | -0.200 | 0.037 | -5.418 | 0.000 | -0.118 | -0.117 |
| Transport ~ Gender | -0.274 | 0.283 | -0.967 | 0.333 | -0.274 | -0.135 |
| Transport ~ Age | -0.010 | 0.119 | -0.087 | 0.930 | -0.010 | -0.012 |
| Transport ~ Income | 0.092 | 0.059 | 1.552 | 0.121 | 0.092 | 0.171 |
| Transport ~ Gender#Attitude | 0.178 | 0.063 | 2.842 | 0.004 | 0.178 | 0.056 |
| Transport ~ Age#Attitude | 0.031 | 0.026 | 1.210 | 0.226 | 0.031 | 0.024 |
| Transport ~ Income#Attitude | 0.021 | 0.014 | 1.441 | 0.149 | 0.021 | 0.171 |
| Transport ~ Gender#Subjective norms | 0.057 | 0.065 | 0.874 | 0.382 | 0.057 | 0.096 |
| Transport ~ Age#Subjective norms | -0.063 | 0.026 | -2.391 | 0.017 | -0.063 | -0.255 |
| Transport ~ Income#Subjective norms | 0.008 | 0.016 | 0.534 | 0.593 | 0.008 | 0.053 |
| Transport ~ Gender#Knowledge of climate impact | 0.033 | 0.051 | 0.650 | 0.516 | 0.033 | 0.065 |
| Transport ~ Age#Knowledge of climate impact | 0.071 | 0.022 | 3.267 | 0.001 | 0.071 | 0.328 |
| Transport ~ Income#Knowledge of climate impact | -0.030 | 0.011 | -2.886 | 0.004 | -0.030 | -0.216 |
| Transport ~ Gender#Barriers to low carbon lifestyle | -0.048 | 0.032 | -1.506 | 0.132 | -0.048 | -0.056 |
| Transport ~ Age#Barriers to low carbon lifestyle | 0.015 | 0.013 | 1.187 | 0.235 | 0.015 | 0.044 |
| Transport ~ Income#Barriers to low carbon lifestyle | 0.003 | 0.007 | 0.476 | 0.634 | 0.003 | 0.016 |
| Shopping behavior ~ Attitude | -0.077 | 0.048 | -1.609 | 0.108 | -0.049 | -0.049 |
| Shopping behavior ~ Subjective norms | 0.402 | 0.031 | 13.000 | 0.000 | 0.345 | 0.340 |
| Shopping behavior ~ Knowledge of climate impact | 0.740 | 0.061 | 12.174 | 0.000 | 0.365 | 0.361 |
| Shopping behavior ~ Barriers to low carbon lifestyle | -0.161 | 0.033 | -4.939 | 0.000 | -0.095 | -0.094 |
| Shopping behavior ~ Gender | -0.254 | 0.266 | -0.956 | 0.339 | -0.254 | -0.126 |
| Shopping behavior ~ Age | 0.013 | 0.114 | 0.117 | 0.907 | 0.013 | 0.016 |
| Shopping behavior ~ Income | 0.023 | 0.059 | 0.384 | 0.701 | 0.023 | 0.042 |
| Shopping behavior ~ Gender#Attitude | 0.172 | 0.058 | 2.952 | 0.003 | 0.172 | 0.054 |
| Shopping behavior ~ Age#Attitude | 0.035 | 0.024 | 1.464 | 0.143 | 0.035 | 0.027 |
| Shopping behavior ~ Income#Attitude | 0.007 | 0.014 | 0.480 | 0.631 | 0.007 | 0.008 |
| Shopping behavior ~ Gender#Subjective norms | -0.048 | 0.057 | -0.838 | 0.402 | -0.048 | -0.082 |
| Shopping behavior ~ Age#Subjective norms | -0.052 | 0.024 | -2.155 | 0.031 | -0.052 | -0.210 |
| Shopping behavior ~ Income#Subjective norms | 0.033 | 0.014 | 2.290 | 0.022 | 0.033 | 0.207 |
| Shopping behavior ~ Gender#Knowledge of climate impact | 0.097 | 0.049 | 2.000 | 0.045 | 0.097 | 0.193 |
| Shopping behavior ~ Age#Knowledge of climate impact | 0.049 | 0.021 | 2.370 | 0.018 | 0.049 | 0.229 |
| Shopping behavior ~ Income#Knowledge of climate impact | -0.018 | 0.011 | -1.687 | 0.092 | -0.018 | -0.131 |
| Shopping behavior ~ Gender#Barriers to low carbon lifestyle | -0.008 | 0.029 | -0.257 | 0.797 | -0.008 | -0.009 |
| Shopping behavior ~ Age#Barriers to low carbon lifestyle | -0.001 | 0.012 | -0.043 | 0.965 | -0.001 | -0.001 |
| Shopping behavior ~ Income#Barriers to low carbon lifestyle | -0.003 | 0.007 | -0.460 | 0.646 | -0.003 | -0.014 |

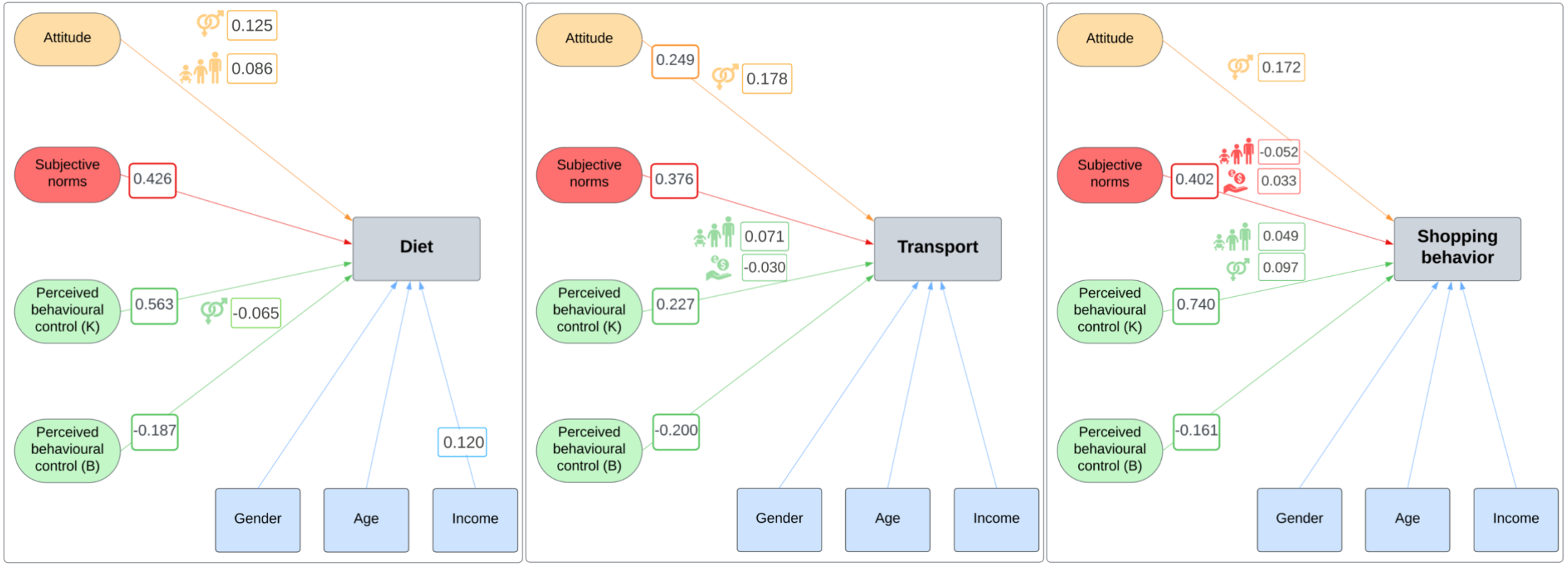


***Figure 11.*** Separate path diagrams for diet, transport, and shopping behavior with only significant weights shown ($p < 0.05$). In displaying the interaction terms, ⚥ stands for *gender*, 👪 for *age*, and 💰 for *income*.

# 5. Conclusion and discussion

In this section, the conclusion and discussion are addressed, presenting the key findings, strengths, and limitations of this study. In addition, recommendations for future research and policy implications are discussed in relation to the strengths and limitations of the study.

## *5.1 Key findings*

The hypotheses were tested using two structural equation models: one without the interaction terms of socioeconomic factors and one that included these interaction terms. In the following sections, the conclusions of both analyses for each TPB element, along with the influence of socioeconomic factors, will be addressed and linked to the existing literature discussed in the literature review.

### *5.1.1 Attitude*

To begin with, the analysis showed that attitude has no significant effect on a low-carbon diet and low-carbon shopping behavior but does exert a positive, significant effect on low-carbon transport. This latter effect is supported by research by Heath & Gifford (2002) who found that a positive attitude towards public transport, made people choose the bus, a form of low-carbon transport, more often. Nevertheless, the non-significant effect of attitude on diet and shopping indicates that attitude alone may not be a sufficient factor in adopting the aspects of a low-carbon lifestyle. This is in line with previous studies that acknowledge that individuals with a positive attitude towards low-carbon behavior may not have the intention to perform this behavior because they are confronted with barriers (Chen, 2007; Vermeir & Verbeke, 2006).

When interaction terms were added to the SEM model, the effect of attitude on transport remained significant, and it even became slightly stronger. In addition, when gender and age interacted with attitude, it showed a significant positive effect on a low-carbon diet and the interaction effect of gender with attitude alone showed significant positive effects on all aspects of a low-carbon lifestyle. The positive interaction of gender with attitude on all aspects, indicates that males with a positive attitude towards a low-carbon lifestyle are more likely to adopt all aspects of a low-carbon lifestyle than females. This is in contrast to what has commonly been found in previous studies. Prior research, including a meta-analysis of 53 recent studies, suggests that females tend to have more positive attitudes towards a low-carbon lifestyle and express more concern about the environment than males (Dietz et al., 2002; Gökmen, 2021; Skogen et al., 2018; Tikka et al., 2000; Zelezny et al., 2000). However, there

are also some studies that find no difference or indicate that males have more positive attitudes towards a low-carbon lifestyle (Chen & Chai, 2010; Hayes, 2001; Mostafa, 2007). The differences between the effects found in previous studies and the effect found in this study may be explained by a different way of measuring the concept of attitude. In this study, an individual's attitude is based on how concerned they are and whether they feel that their personal lifestyle choices are important in the broader context of climate change. Other studies measure attitudes in other ways, sometimes fairly similar to the method used in this study, sometimes dissimilar. For example, Zelezny et al. (2000) refer to a study using the NEP scale from Dunlap & Van Liere (1978) to measure attitudes. This is a more comprehensive and detailed measure. Another possible explanation could be the current changing zeitgeist, such as the growing focus on sustainability and climate change (Baiardi, 2023). This may have a greater impact on males' attitudes, so that in some contexts males may become more involved in environmental issues due to changing social norms and expectations. Strieder Philippssen et al. (2017) also point out that conflicting conclusions have been found regarding the effect of gender and suggest that the role that gender plays in environmental attitudes and behaviour may be more complicated than previously thought. They offer the possible explanation that the relationship between gender and the environment has changed in recent years, weakening the tendency for females to be more influential than males in terms of environmental awareness (Zelezny et al. 2000).

Furthermore, the positive interaction of age with attitude on a low-carbon lifestyle indicates that older individuals with a positive attitude towards a low-carbon lifestyle are more likely to adopt a low-carbon diet. The scientific field offers both support and contradiction for this effect, and there seems to be no clear consensus yet (Lehikoinen & Salonen, 2019; (Wiernik et al., 2013).

In conclusion, the first hypothesis, that attitude has a positive effect on the adoption of a low-carbon lifestyle, can only be partially accepted. Attitude indeed has a positive effect on the adoption of low-carbon transport, but this effect remains absent in the case of diet and shopping behavior. However, for males and older individuals there could be a positive effect of attitude on a low-carbon diet and for males there could be a positive effect of attitude on low-carbon shopping behavior.

### *5.1.2 Subjective norms*

Secondly, the analyses showed that subjective norms had a positive and significant influence on all three aspects of a low-carbon lifestyle. This finding supports previous research that found

that social norms can exert great influence on sustainable behavior (Swaim et al., 2014; Vermeir & Verbeke, 2006).

The interaction terms with subjective norms in the second SEM model showed significant effects of age and income on the adoption of low-carbon shopping behavior. These effects suggest that younger individuals and higher income individuals are more sensitive to the influence of subjective norms on their shopping behavior than older individuals and individuals with less income. This is consistent with research by Johnstone & Lindh (2022) who found that that younger consumers, particularly millennials, were more sensitive to the sustainability standards around them and that 'influencers' could increase sustainability awareness within this group. Furthermore, many studies find that people with higher incomes are more likely to adopt a low-carbon lifestyle because they have more resources, but the effect that people with higher incomes are more sensitive to subjective norms and therefore more influenced by them in their shopping behavior is not supported by previous studies (Franzen & Vogl, 2013; Szulc-Obłoza & Żurek, 2024). Bai & Bai (2020) found that cost consciousness, the extent to which individuals take financial costs into account when making decisions about their behavior, had no significant effect on the relationship between social norms and environmental behavior. In other words, even if individuals are cost-conscious, they will still engage in socially acceptable behavior regardless of the cost. This suggests that subjective norms play a positive role in sustainable behavior, regardless of an individual's income. This is consistent with the findings of this study. However, it does not answer the observed effect that higher income individuals would be more sensitive to subjective norms. To the researcher's knowledge, no prior study has investigated this specific effect, suggesting that this may be a new and important finding in the field.

In conclusion, the second hypothesis, that subjective norms have a positive effect on the adoption of a low-carbon lifestyle, is supported by the analyses in this study. However, in the case of shopping behavior, the effect of subjective norms decreases slightly with age and increases with income.

### *5.1.3 Perceived behavioral control*

Thirdly, the analyses showed that perceived behavioral control (PBC) had different influences on the aspects of a low-carbon lifestyle. PBC was measured using two latent variables: knowledge of climate impact and barriers to a low-carbon lifestyle. The analyses showed that knowledge about climate impact had a positive influence on the aspects of a low-carbon lifestyle, while barriers to a low-carbon lifestyle had a negative influence. This supports what was found in the literature: perceived control is in fact an important component to consider

while studying the adoption of a low-carbon lifestyle (Biasini et al., 2021; Gardner & Abraham, 2007). In addition, it was noted that the strength of the effects of knowledge in both models differed among the three aspects of a low-carbon lifestyle. The effect of knowledge was significantly smaller for low-carbon transport than for diet and shopping. However, the effect of knowledge on low-carbon shopping behavior was significantly the largest of the three aspects and also the largest significant effect in the full SEM analysis. Therefore, knowledge can be seen as a very important influence. This is consistent with several studies showing that knowledge is an important predictor of sustainable behavior (Chan, 1999; Vining and Ebreo, 1990).

The other element of PBC within this study, barriers to a low-carbon lifestyle, had a consistent negative, significant influence on the aspects of a low-carbon lifestyle. Although the magnitude of the negative effect differed slightly between aspects, the difference was not substantial. However, there was a clear distinction between the various aspects with regard to their interaction terms. In particular, there was a statistically significant negative interaction between gender and barriers to adopting a low-carbon diet. This indicates that the impact of perceived barriers on a low-carbon diet is more pronounced for males than for females. This finding is consistent with previous research indicating that males experience greater barriers than females when making sustainable food choices (Gifford & Chen, 2017).

Moreover, the interaction terms with knowledge about climate impact showed that the effects of this predictor were modulated by gender, age, and income. The interaction with age had a positive influence on low-carbon transport and shopping behavior, indicating that older individuals with more knowledge about their climate impact were more likely to adopt low-carbon transport and shopping behavior. In addition, the interaction effect of gender and knowledge also showed that for males there was a greater positive influence of knowledge on low-carbon shopping behavior than for females. This corresponds to the findings of earlier research that males have greater knowledge of the environment (Arcury, 1990; Blocker and Eckberg, 1997; Hayes, 2001).

However, for higher income individuals, the positive influence of knowledge about climate impact on low-carbon transport was weaker. This suggests that higher income individuals are less likely to act on the knowledge they possess about their climate impact when making choices about low-carbon transport. This effect could stem from the fact that higher income individuals can afford to drive cars or travel by plane for vacations, and they do so despite being aware of their climate impact. Individuals with lower incomes and the same level of knowledge as these higher income individuals cannot afford to drive cars or travel by plane

and therefore do not do so (Kleinhückelkotten et al., 2016). However, it is necessary to interpret this support with caution, given that this study was conducted in Germany and therefore less generalizable to China.

In conclusion, the third hypothesis, that perceived behavioral control has a positive effect on the adoption of a low-carbon lifestyle, is partially supported by the analyses in this study. While knowledge positively influences a low-carbon lifestyle, barriers to a low-carbon lifestyle negatively influences this. In addition, the effect of knowledge on low-carbon shopping behavior is larger for males and older individuals and the effect on low-carbon transport is smaller for individuals with higher incomes.

### *5.1.4 Socioeconomic factors*

Finally, it was investigated whether socioeconomic factors, including gender, age and income, exert direct or indirect influence on the relationship between the elements of the TPB and the adoption of a low-carbon lifestyle. Not all interaction terms showed significant effects, but a reasonable proportion did. Furthermore, the results indicated that only income had a significant positive direct effect on the adoption of a low-carbon diet. This is consistent with existing research which indicates that a low-carbon diet is more feasible for individuals with greater financial resources (Chen & Zhong, 2022).

First, the interaction terms involving gender show significant moderating effects on the relationship between attitude and all elements of a low-carbon lifestyle. This indicates that males with a positive attitude towards a low-carbon lifestyle are more likely to adopt all elements of a low-carbon lifestyle than females. But in the case of diet, men tend to perceive barriers as a greater negative influence to adopt a low-carbon diet. As noted before, the positive interaction effect of attitude with gender, is in contrast to what has commonly been found in previous studies, as they suggest that females tend to have more positive attitudes towards a low-carbon lifestyle than males (Dietz et al., 2002; Gökmen, 2021; Skogen et al., 2018; Tikka et al., 2000; Zelezny et al., 2000). Although there are also studies that do not find a difference or, on the contrary, show that males have more positive attitudes, it is more frequently found that females have more positive attitudes. Overall, there is no clear consensus in the literature (Chen & Chai, 2010; Hayes, 2001; Mostafa, 2007).

Second, age significantly influences several effects: the effect of attitude on low-carbon diet, the effect of knowledge of climate impact on low-carbon transport and shopping behavior and the effect of subjective norms on shopping behavior. The results show that older individuals with a positive attitude towards a low-carbon lifestyle are more likely to adopt a low-carbon

diet, consistent with the literature indicating that older individuals tend to be more conscientious about the earth and its resources (Wiernik et al., 2013). Furthermore, older individuals with greater climate knowledge are more likely to adopt low-carbon transport and shopping behavior, though the positive influence of subjective norms on shopping behavior decreases with age.

Third, income also moderates the influence of TPB elements. Income negatively influences in interaction with knowledge of climate impact on transport and positively influences with subjective norms on shopping behavior. This implies that higher income individuals experience a stronger influence of subjective norms on their shopping behavior, suggesting that social expectations play a significant role in their sustainable behavior choices. As mentioned previously, this effect cannot be supported or contradicted by previous studies. Therefore, this conclusion should be interpreted with caution and further research is recommended.

Moreover, as income increases, the positive impact of climate knowledge on transport diminishes. As noted previously, this effect could stem from the fact that higher income individuals can afford to drive cars or travel by plane for vacations, and they do so despite being aware of their climate impact. This may be related to other research which has found that people from affluent areas perceive climate change as a threat to other parts of the world or to future generations, but less of a threat to themselves (Leiserowitz et al., 2023).

The fourth hypothesis, that socioeconomic factors modulate the effect of the TPB elements on the adoption of a low-carbon lifestyle, can therefore be partially accepted: gender, age, and income modulate *a reasonable portion* of these effects, according to the analyses in this study.

### *5.2 Differences between SEM and correlation results*

The findings from the SEM analysis and the analysis of the correlations show notable differences. To begin with, the SEM model without interaction shows a negative effect of attitude on shopping behavior, but the correlation between attitude and shopping behavior is positive and significant, similar to all correlations between attitude and the aspects of a low-carbon lifestyle. In addition, the correlations between the three aspects of a low-carbon lifestyle are positive and significant as well, but within the SEM analysis they have different relations with the TPB elements. This difference can be explained by several factors.

First, the SEM model in which attitude has a negative effect considers the other TPB elements: subjective norms, knowledge about climate impact and barriers to a low-carbon

lifestyle. The use of these latent variables and the ability to model complex interrelationships can provide a deeper understanding of constructs and their interactions. In contrast, the correlation only shows a direct relationship, which may thus lead to different conclusions about the role of attitude in this case.

Secondly, the SEM model with interaction terms suggests that the relationship between attitude and aspects of a low-carbon lifestyle is moderated by age and gender. For example, older individuals and males with a positive attitude are more likely to adopt a low-carbon diet. These individual differences add complexity to the relations that cannot be captured by a correlation analysis.

In addition, there are reasonably high correlations between the TPB elements and between the aspects of a low-carbon lifestyle. The latter suggests that being engaged in one aspect of a low-carbon lifestyle is likely to be correlated with the other aspects. Despite these high correlations, the SEM analysis shows that subjective norms and knowledge about climate impact consistently have a positive impact on all three aspects, while attitudes and barriers to a low-carbon lifestyle have varying effects. This different effect could be attributed to the fact that within a SEM analysis, multicollinearity is considered and also controlled for in the assumptions prior to the analyses. Therefore, an SEM can give a clearer idea of the actual effects of each variable without multicollinearity problems.

In conclusion, the differences between SEM and correlation results highlight the importance of robust approaches such as SEM. While correlations can only offer insights into direct relationships, SEM can model latent variables, differences between TPB elements and the influence of demographic factors.

### *5.3 Comparative analysis with other studies and policy recommendations*

Comparing these results with other studies indicates both consistencies and differences. For instance, studies in the EU and US also highlight the positive role of subjective norms and knowledge of climate impact (Hassan et al., 2018; Heeren et al., 2016). However, the non-existent influence of attitude on diet and shopping behavior in this study differs from what was found in other Western studies. This could indicate cultural differences in how attitude translates into behavior (Rex et al., 2015). Chinese consumers may be influenced more by social norms and the knowledge they have than by personal attitudes (Bai & Bai, 2020).

In addition, an opposite effect of the role of gender was found compared to the majority of findings from other studies. This suggests a possible new insight, that the dynamics

surrounding males and females in China are changing, and hence their behaviour. This could be further explored in future research.

In conclusion, the main important finding was the strong influence of knowledge of climate impact on all three aspects of a low-carbon lifestyle. Furthermore, given the younger generation's greater sensitivity to subjective norms, it may be effective to demonstrate, through online campaigns, the prevalent norms and the actions of their peers in response to climate change.

### *5.4 Strengths*

The first strength of this study is to examine TPB elements on different aspects of a low-carbon lifestyle. Previous studies primarily focused on the effect of TPB factors on a low-carbon lifestyle in general or just one aspect of it (Biasini et al, 2021; Hassan et al., 2018; Heeren et al., 2016; Kumar, 2012; Klöckner, 2021; Ogiemwonyi et al., 2023; Rex et al., 2015; Zhu et al. 2020). But this study attempts to fill this gap by analyzing multiple different aspects of a low-carbon lifestyle. The results show that subjective norms and perceived behavioral control exert similar influences on the three aspects of a low-carbon lifestyle. However, the effects of attitude and knowledge of climate impact vary significantly depending on the specific behavior. While attitude has a negative impact on diet and shopping behavior, it has a positive impact on low-carbon transport. In addition, although the influence of perceived barriers is consistently negative across all elements, it varies in strength. The remarkably strong effect of knowledge on shopping behavior also demonstrates the value of measuring the aspects separately. The effect might have been underestimated if it had been measured together with the other aspects. Thus, by examining these aspects separately, this research shows that the relationships between TPB elements and a low-carbon lifestyle can be different for each aspect of a low-carbon lifestyle. Therefore, this study highlights that interventions should consider possible differences between aspects of a low-carbon lifestyle rather than approaching low-carbon lifestyle as a single concept. This research thereby offers a holistic view of the influence of the TPB.

The second strength of this research is the study population. This strength is twofold: on the one hand, information is available from a very large number of respondents. Based on the rule of thumb (10-20 times the number of parameters), SEM requires a sample size of at least 750-1500 respondents to obtain reliable estimates for this specific model. A sample size of 3666 respondents is therefore more than sufficient and well suitable for a complex analysis like this. On the other hand, data was consciously collected from a large group of diverse respondents, representing a very large portion of the actual Chinese population. This has

ensured that there is an almost equal distribution of males and females, the age categories up to 60 years are mostly evenly distributed, and that there are enough (at least 54 respondents) in each income group. However, the last variable is more difficult to even out as certain income groups are harder to reach or there are fewer people in these groups at all. Altogether, it remains a very diverse, representative group, making the research strong as it can be generalized to a large part of the Chinese population.

The third strength of this study is the inclusion of the socioeconomic factors gender, age and income in the analyses. By considering differences between demographic groups, it becomes clear that the influences of the TPB elements are not uniform. This shows that demographic heterogeneity can be an important aspect to consider when developing (policy) interventions to promote low-carbon lifestyles. For example, the effect of knowledge about climate impact is greater for older individuals than for younger individuals. Therefore, it may be useful to target interventions aimed at informing individuals specifically at older individuals.

### *5.5 Limitations*

One of the limitations of this study is the absence of a question in the questionnaire that measures the respondent's education level. Previous research has shown that individuals with higher levels of education also have greater access to education and knowledge about a low-carbon lifestyle. Research indicates that individuals with more knowledge about sustainable options are more likely to choose these sustainable alternatives. Due to the lack of a variable measuring education level, not all expected influential socioeconomic factors could be included in the model with interaction terms. Attitude, subjective norms, and perceived behavioral control may have stronger or weaker relationships with the aspects of a low-carbon lifestyle if education level had been included in the analyses.

A second limitation of this research is the way the latent variables were constructed. For instance, attitude and subjective norms have two indicators, and the knowledge of climate impact and barriers for a low-carbon lifestyle (PBC) have respectively three and eight indicators. Although the indicators generally fit well with their respective latent variables according to the standardized factor loadings and their significance, the unequal number of indicators may influence the robustness of the measurements of the latent variables. Besides the practical limitation regarding the number of indicators, there is also a substantive limitation here. The questions that serve as indicators of the TPB elements were chosen with care, but could not in all cases question the actual, full scope of the concept. For instance, attitude measures the extent to which a respondent is concerned and whether he or she feels that his or

her personal choices affect the climate problem. However, this is unlikely to reflect a person's attitude perfectly and thus the findings from this study should be interpreted with caution. Building on this, in this study it was chosen to construct PBC as two latent variables rather than a single latent variable. The questions from the available questionnaire were a limitation in this regard. There were no suitable questions that could together form a single latent variable for perceived behavioral control. Therefore, in future research it is advised to develop a specific measurement instrument to capture the concept as accurately as possible.

A fourth possible limitation is the potential for non-response bias. Of the 4000 WeChat users approached, 334 users did not complete one or more questions and were therefore excluded from the analysis. This exclusion could imply that the group who did not respond systematically differs from those who did. For instance, it is possible that those who did not complete the questionnaire have less affinity with the subject matter or might find it a confronting topic, potentially leading to biased results. It is important to acknowledge this limitation as it may affect the generalizability of the findings. Future research could try to minimize non-response bias by requiring respondents to complete all questions and giving them a reward for doing so or by sending a reminder.

### *5.6 Key message*

This study shows that mainly knowledge of climate impact and subjective norms play a major role in predicting aspects of a low-carbon lifestyle. In addition, barriers can have a smaller but significant negative impact on the adoption of this type of behavior. Finally, the findings in this study show the added value of examining different aspects of a low-carbon lifestyle and including socio-economic factors to get a clearer view of what works, for whom.

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# 7. Appendices

## *Appendix I*

*Operationalisations*

*Independent variable latent attitude*

The independent latent variable attitude was measured through two indicators: *'How worried are you about the impact of climate change on the future living environment?'* and *'To what extent do you think that personal lifestyle choices can contribute to saving energy, reducing emissions, and other measures addressing climate change?'*

For the first question, the following response categories were given:

- Not at all worried (01)
- Not very worried
- Sometimes worried
- Very worried (04)

For the second question, the following response categories were given:

- Not at all (01)
- 02
- 03
- 04
- A great deal (05)
- Don't know (06)

*Independent latent variable subjective norm*

The independent latent variable subjective norm was measured through two indicators: *'What is the view of your close family members on a low-carbon lifestyle?'* and the question *'What is the view of your friends on a low-carbon lifestyle?'* into one variable with giving both questions an equal weight as they contribute an equal amount. The following response categories were given:

- Very supportive (01)
- Support

- They don't care, or rarely think about it
- Against (04)

To make the analyses more intuitive, the scale of the variable has been reversed, such that a higher score reflects greater support from friends and close family members for a low-carbon lifestyle.

*Independent latent variable perceived behavioral control*

The independent variable perceived behavioral control was measured by two latent variables: self-reported knowledge levels on sustainability themes and perceived barriers encountered by respondents in adopting a low-carbon lifestyle. This approach was chosen because it was not feasible to create a single latent variable from these indicators due to the significantly different measurement methods of the questions. Combining the rating of potential barriers with the knowledge level into one latent variable was attempted and tested in the model, but it did not adequately represent the concept of 'perceived behavioral control.' Therefore, it was decided to construct two separate latent variables. This way, the two variables together can provide a good representation of the respondents' knowledge regarding the impact of different facets of behavior, despite any obstacles they may face.

Knowledge of climate impact was measured through three indicators:

1. *'Our daily choices of lifestyle have different impacts on energy conservation, emission reduction and climate change. How much do you know about them?'*
    - Hereby there were given four topic options for which the respondent could indicate how much he or she knows about it:
        - Climate impacts of different modes of travel
        - Climate effects of different diets
        - Climate impact of different shopping habits
    - The following response categories were given:
        - Not at all (01)
        - (02)
        - (03)
        - (04)
        - A great deal (05)

Barriers to a low-carbon lifestyle was measured through eight indicators:

2. *'For you, what are the reasons keeping you away from low-carbon lifestyle? Rate the options below. 5 stars indicates it is the most important reason and vice versus for 1 star.'*
    a. I don't see why we need a low-carbon lifestyle
    b. I am occupied by other practical concerns of my own living
    c. No one told me what to do
    d. It is time-consuming and not convenient
    e. Low carbon alternatives are usually more expensive
    f. There is no adequate infrastructure and policies to support it
    g. It is difficult to change the habits
    h. No one around me is doing it

*Independent variables socioeconomic factors*

The independent variables socioeconomic factors were measured through three questions about the individual's gender, age, and income.

*Gender*

To answer the question asking the respondent's gender, the following response categories were given:

- Female (01)
- Male (02)
- Others
- Prefer not to tell

Since 'others' and 'prefer not to tell' were not indicated by any of the respondents, the gender variable can be treated as a binary variable.

*Age*

To answer the question asking the respondent's age, the following response categories were given:

- 18-30 years old (01)
- 31-40 years old
- 41-50 years old

- 51-60 years old
- 60 years old
- Prefer not to tell (06)

*Income*

To answer the question asking the respondent's income (per head), the following response categories were given:

- <400 RMB (01)
- 400~900 RMB
- 900~1300 RMB
- 1300-1800 RMB
- 1800~2500 RMB
- 2500~3200 RMB
- 3200~4500 RMB
- 4500~8000 RMB
- 8000~15000 RMB
- 15,000 RMB (10)
- Prefer not to tell

*Dependent variables*

The dependent variables diet, transport and shopping behavior were measured through the questions given below. For all questions the following response categories were given:

- Often (01)
- Sometimes
- In a small number of cases
- Rarely
- Never (05)

*Diet*

The dependent variable change of diet was measured through the question: *'How often do you think about environmental impacts when choosing the food that you eat?'*

*Transport*

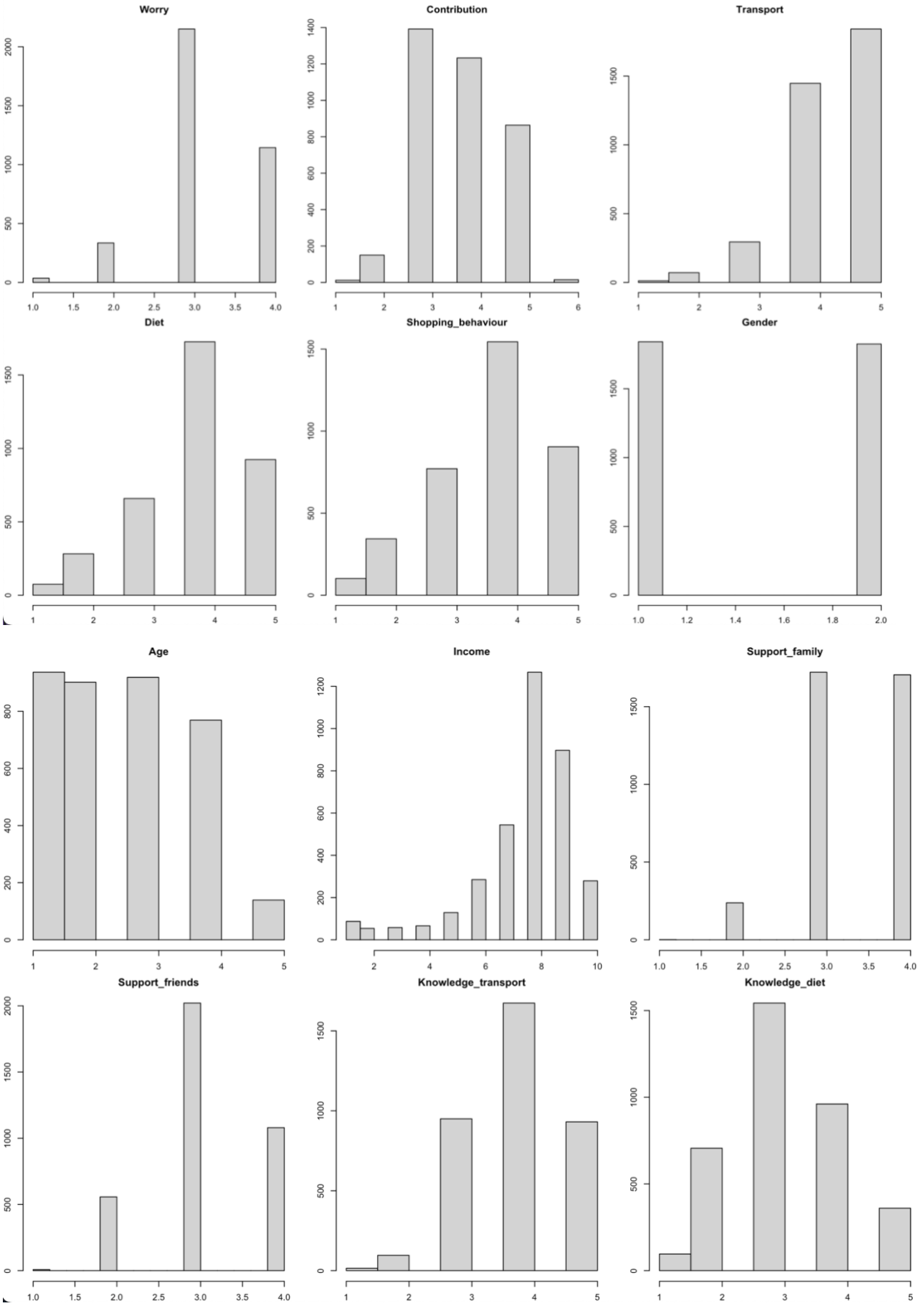
The dependent variable change of transport was measured through the question: *'How often do you consciously choose more environmentally friendly modes of transport?'*

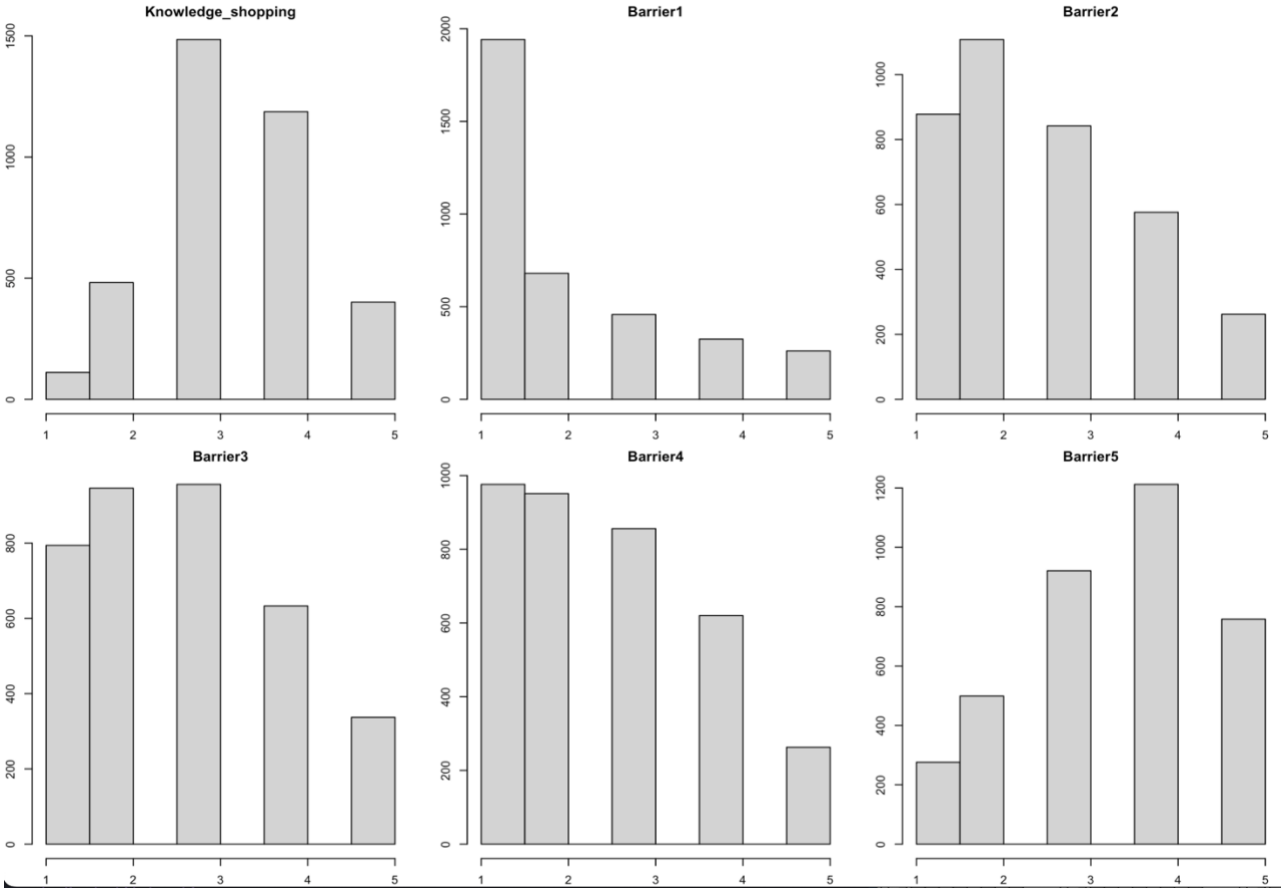
*Shopping behavior*

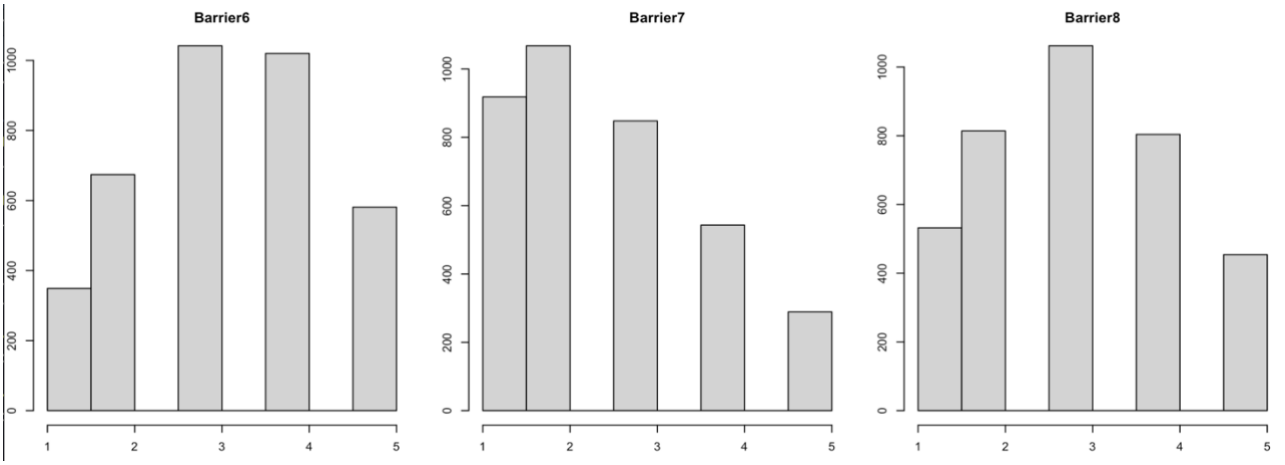
The dependent variable change of shopping behavior was measured through the question: *'How often do you consider the environmental impact of the products when you are shopping?'*

To make the analyses more intuitive, the scale of these variables has been reversed, such that a higher score reflects greater proclivity towards sustainable intentions.

*Frequency tables*




Knowledge_shopping
Barrier1
Barrier2
Barrier3
Barrier4
Barrier5


Barrier6
Barrier7
Barrier8

# *Appendix II*

## Frequencies indicators of latent constructs of PBC

*Table 7: Frequencies and percentages of the indicators of the latent constructs of PBC*

| Indicator | Category | Frequency | Percentage |
|---|---|---|---|
| **Knowledge transport** | Not at all (01) | 15 | 0.4% |
| | 02 | 96 | 2.6% |
| | 03 | 950 | 25.9% |
| | 04 | 1674 | 45.7% |
| | A great deal (05) | 931 | 25.4% |
| **Knowledge diet** | Not at all (01) | 96 | 2.6% |
| | 02 | 706 | 19.3% |
| | 03 | 1543 | 42.1% |
| | 04 | 961 | 26.2% |
| | A great deal (05) | 360 | 9.8% |
| **Knowledge shopping** | Not at all (01) | 111 | 3.0% |
| | 02 | 482 | 13.2% |
| | 03 | 1485 | 40.5% |
| | 04 | 1187 | 32.4% |
| | A great deal (05) | 401 | 10.9% |
| **Barrier1** | 1 | 1942 | 53.0% |
| | 2 | 680 | 18.6% |
| | 3 | 458 | 12.5% |
| | 4 | 325 | 8.9% |
| | 5 | 261 | 7.1% |
| **Barrier2** | 1 | 878 | 24.0% |
| | 2 | 1108 | 30.2% |
| | 3 | 842 | 23.0% |
| | 4 | 576 | 15.7% |
| | 5 | 262 | 7.2% |
| **Barrier3** | 1 | 794 | 21.7% |
| | 2 | 946 | 25.8% |
| | 3 | 956 | 26.1% |
| | 4 | 633 | 17.3% |

| Indicator | Category | Frequency | Percentage |
|---|---|---|---|
| | 5 | 337 | 9.2% |
| **Barrier4** | 1 | 976 | 26.6% |
| | 2 | 951 | 25.9% |
| | 3 | 856 | 23.4% |
| | 4 | 620 | 16.9% |
| | 5 | 263 | 7.2% |
| **Barrier5** | 1 | 276 | 7.5% |
| | 2 | 499 | 13.6% |
| | 3 | 921 | 25.1% |
| | 4 | 1212 | 33.1% |
| | 5 | 758 | 20.7% |
| **Barrier6** | 1 | 349 | 9.5% |
| | 2 | 674 | 18.4% |
| | 3 | 1042 | 28.4% |
| | 4 | 1020 | 27.8% |
| | 5 | 581 | 15.9% |
| **Barrier7** | 1 | 918 | 25.0% |
| | 2 | 1068 | 29.1% |
| | 3 | 848 | 23.1% |
| | 4 | 543 | 14.8% |
| | 5 | 289 | 7.9% |
| **Barrier8** | 1 | 532 | 14.5% |
| | 2 | 814 | 22.2% |
| | 3 | 1062 | 29.0% |
| | 4 | 804 | 21.9% |
| | 5 | 454 | 12.4% |

*Table 8: Frequencies and percentages of the socioeconomic factors*

| *Variable* | *Category* | *Frequency* | *Percentage* |
|---|---|---|---|
| **Gender** | Male | 1825 | 49.8% |
| | Female | 1841 | 50.2% |
| **Age** | 18-30 years old | 937 | 25.6% |
| | 31-40 years old | 902 | 24.6% |
| | 41-50 years old | 919 | 25.1% |
| | 51-60 years old | 769 | 21.0% |
| | 60 years old | 139 | 3.8% |
| **Income** | <400 RMB | 87 | 2.4% |
| | 400~900 RMB | 54 | 1.5% |
| | 900~1300 RMB | 58 | 1.6% |
| | 1300-1800 RMB | 66 | 1.8% |
| | 1800~2500 RMB | 129 | 3.5% |
| | 2500~3200 RMB | 285 | 7.8% |
| | 3200~4500 RMB | 544 | 14.8% |
| | 4500~8000 RMB | 1267 | 34.6% |
| | 8000~15000 RMB | 897 | 24.5% |
| | 15,000 RMB | 279 | 7.6% |

*Table 9: Loading factors of indicators of latent variables*

| *Variable* | *Indicator* | *Estimate* | *Std. Err* | *z-value* | *P(>\|z\|)* | *Std. lv.* |
|---|---|---|---|---|---|---|
| **Attitude** | Worry | 1.000 | | | | 0.637 |
| | Contribution | 1.020 | 0.046 | 22.042 | 0.000 | 0.650 |
| **Subjective norms** | Support family | 1.000 | | | | 0.857 |
| | Support friends | 0.866 | 0.024 | 35.677 | 0.000 | 0.742 |
| **PBC1: Knowledge** | Knowledge transport | 1.000 | | | | 0.494 |
| | Knowledge diet | 1.527 | 0.060 | 25.256 | 0.000 | 0.754 |
| | Knowledge shopping | 1.553 | 0.062 | 25.003 | 0.000 | 0.767 |
| **PBC2: Barriers** | Barrier1 | 1.0000 | | | | 0.591 |
| | Barrier2 | 1.227 | 0.034 | 35.984 | 0.000 | 0.725 |
| | Barrier3 | 1.127 | 0.032 | 35.737 | 0.000 | 0.666 |
| | Barrier4 | 1.220 | 0.034 | 35.963 | 0.000 | 0.722 |
| | Barrier5 | 0.759 | 0.032 | 23.850 | 0.000 | 0.449 |
| | Barrier6 | 0.907 | 0.031 | 29.115 | 0.000 | 0.536 |

| | | | | | |
|---|---|---|---|---|---|
| Barrier7 | 1.210 | 0.034 | 35.869 | 0.000 | 0.715 |
| Barrier8 | 1.157 | 0.034 | 34.134 | 0.000 | 0.684 |

## *Appendix III*

*Assumptions Structural Equation Model*

In this section the assumptions for SEM are tested and discussed. As the data in this study is categorical and ordinal distributed, some of the assumptions of SEM are adapted to this situation (Finney & DiStefano, 2006).

### 1. Normality

Although normality is not applicable for categorical data, the distribution of the variables can be examined. The plots of the frequency distribution of all variables can be found in Appendix I. The frequency distributions indicate that the dependent variables are positively skewed, with participants generally showing support for the aspects of a low-carbon lifestyle. In particular the low-carbon transport variable is clearly skewed. Therefore, the WLSMV (weighted least squares mean and variance adjusted) estimator is used for the SEM analyses. This estimator is well suited to categorical data as it can provide robust parameter estimates and standard errors even when the normality hypothesis is violated (Hong et al., 2024). This estimator also deals with non-normality and ordinality of the data, making it a suitable choice for this analysis.

### 2. Linearity

The linearity assumption is also relaxed for categorical data. Instead, the focus is on the appropriateness of the logistic or probit link functions that are used for the categorical outcomes. The distribution of the categorical variables and the model fit indices were examined in order to ensure the appropriateness of the link functions (logit or probit) used in the SEM analysis for categorical data. The frequency distributions indicated that the categories are well-distributed, which supports the use of these link functions. Additionally, the model fit indices (CFI, TLI, RMSEA, SRMR) fall within acceptable ranges, which also suggests that the chosen link functions appropriately model the relationships in the data. Therefore, it can be concluded that the logit or probit link functions used in the SEM are suitable for the data.

### 3. Multicollinearity

Multicollinearity occurs when two or more predictors in a SEM model are highly correlated, which can affect the reliability of coefficient estimates and complicate model interpretation. Identifying and addressing multicollinearity is crucial for obtaining robust and reliable model results.

To identify multicollinearity, variance inflation factors (VIF) values are typically calculated for each predictor in a linear regression context. However, as this research involves latent variables in a structural equation model (SEM), a different approach for these variables was taken.

For latent variables, the correlations between them were examined. Table 4 on page 29 shows all correlations. None of the correlations exceeded the threshold of 0.80, indicating that multicollinearity is not a significant concern in this model. The highest correlations observed were between *attitude* and *subjective norms* (0.575), *attitude* and *knowledge of climate impact* (0.548), and *subjective norms* and *knowledge of climate impact* (0.501). These values are well below the threshold, ensuring the stability and reliability of the model parameters.

For observed variables, the Spearman's rank correlations are examined. The highest correlations were observed between *diet* and *shopping behavior* (0.527), and *diet* and *subjective norms* (0.608). While these correlations are relatively high, they do not exceed the critical threshold of 0.80, indicating that multicollinearity is not likely to severely affect the estimates for observed variables either.

For observed predictors gender, age and income, the values of the VIF could be calculated. The values are 1.093890, 1.102021 and 1.034255, respectively. As these values fall well below the commonly used threshold of 5, it can be concluded that there is no significant multicollinearity.

In summary, both latent and observed variable correlations and VIF values indicate that multicollinearity is not a significant issue in this model, ensuring the robustness and reliability of the coefficient estimates.

4. **Sample size**

Given the complexity of the chosen model, which includes multiple latent variables and interactions, having a sample size of 3666 is well above the recommended minimum.

5. **Measurement model fit:**

Ensuring the fit of the measurement model is critical for validating that the indicators correctly measure the underlying latent constructs. To evaluate the measurement model fit, there was first a confirmatory factor analysis (CFA) conducted to assess the relationships between observed variables (indicators) and their respective latent constructs (attitude, subjective norms, knowledge of climate impact (PBC), and barriers to a low-carbon lifestyle (PBC)).

Subsequently, key fit indices including Chi-square ($\chi^2$), comparative fit index (CFI), Tucker-Lewis index (TLI), root mean square error of approximation (RMSEA), and standardized root

mean square residual (SRMR) were conducted. Table 9 and table 10 represent the fit indices, respectively.

*Table 10: Fit indices for the SEM model without interaction terms*

| Fit index | Value (standardized) | Value (scaled) |
|---|---|---|
| Chi-square test of model fit | 558.981 | 779.876 |
| Degrees of freedom | 109 | 109 |
| Comparative fit index (CFI) | 0.993 | 0.981 |
| Tucker-Lewis index (TLI) | 0.991 | 0.974 |
| Root mean square error of approximation (RMSEA) | 0.034 | 0.041 |
| Standardized root mean square residual (SRMR) | 0.031 | 0.031 |

*Table 11: Fit indices for the SEM model with interaction terms*

| Fit index | Value (standardized) | Value (scaled) |
|---|---|---|
| Chi-square test of model fit | 1281.135 | 960.088 |
| Degrees of freedom | 334 | 334 |
| Comparative fit index (CFI) | 0.986 | 0.982 |
| Tucker-Lewis index (TLI) | 0.993 | 0.992 |
| Root mean square error of approximation (RMSEA) | 0.028 | 0.023 |
| Standardized root mean square residual (SRMR) | 0.029 | 0.029 |

Overall, the fit indices suggest that both models have a good fit with the data. This means that both the model without and the model with interaction terms provide a robust and reliable representation of the relationships within the data. Incorporating the interaction terms provides additional insight into the influence of socio-demographic factors without compromising the model fit.

6. **Outliers:**

Outliers were identified using Cook's distance for the SEM model. Cases with Cook's distance greater than the threshold of $4/N$ (where $N$ is the number of observations) were considered influential. In the data 431 influential cases were identified. Therefore, a subset of data excluding the influential cases was created and the SEM model was refitted using the cleaned data. Fit indices for both the original and cleaned models were compared to assess the impact of influential cases. Parameter estimates for both models were compared to assess the changes in the relationships between variables due to the removal of influential cases.

- Original model parameter estimates:
    - For example, diet ~ attitude: Estimate = -0.020, Std. Error = 0.045, p = 0.665
    - Transport ~ Attitude: Estimate = 0.347, Std. Error = 0.049, p < 0.001
- Cleaned model parameter estimates:

- For example, Diet ~ Attitude: Estimate = -0.043, Std. Error = 0.063, p < 0.000
- Transport ~ Attitude: Estimate = 0.347, Std. Error = 0.063, p < 0.000

The fit indices and parameter estimates for the model without influential cases were compared to the original model. The results indicated that the removal of influential cases did not significantly alter the overall fit of the model, as evidenced by similar values for CFI, TLI, RMSEA, and SRMR. However, some parameter estimates did show changes, which suggests that while the overall model structure remains stable, the influence of certain observations may affect specific relationships within the model. This highlights the importance of considering the presence of influential cases when interpreting the specific paths within the SEM model. Given these findings, table 11 reports the results without the influential cases to provide a comprehensive view of the model's robustness and the potential impact of outliers.

7. **Missing Data:**

To ensure the integrity of the dataset used for the SEM analysis, the presence of missing data was assessed. The dataset comprises 3666 respondents, and an evaluation of each variable was conducted to identify any missing values. The results indicate that there are no missing values across all variables, thus, the assumption of no missing data is met, supporting the robustness of the subsequent SEM analysis.

*Table 12: Results SEM analysis with interaction terms with cleaned data (without outliers)*

| Path | Estimate | Std. Err | z-value | P(>\|z\|) | Std. lv. |
|---|---|---|---|---|---|
| Diet ~ Attitude | -0.043 | 0.053 | -0.809 | 0.418 | -0.026 |
| Diet ~ Subjective norms | 0.499 | 0.034 | 14.832 | 0.000 | 0.424 |
| Diet ~ Knowledge of climate impact | 0.628 | 0.074 | 8.507 | 0.000 | 0.298 |
| Diet ~ Barriers to low carbon lifestyle | -0.141 | 0.034 | -4.147 | 0.000 | -0.085 |
| Diet ~ Gender | -0.104 | 0.308 | -0.338 | 0.735 | -0.104 |
| Diet ~ Age | 0.412 | 0.135 | 3.061 | 0.002 | 0.412 |
| Diet ~ Income | -0.214 | 0.094 | -2.281 | 0.023 | -0.214 |
| Diet ~ Gender#Attitude | 0.136 | 0.071 | 1.921 | 0.055 | 0.136 |
| Diet ~ Age#Attitude | 0.050 | 0.030 | 1.644 | 0.100 | 0.050 |
| Diet ~ Income#Attitude | 0.012 | 0.021 | 0.574 | 0.566 | 0.012 |
| Diet ~ Gender#Subjective norms | 0.053 | 0.066 | 0.813 | 0.416 | 0.053 |
| Diet ~ Age#Subjective norms | -0.083 | 0.029 | -2.895 | 0.004 | -0.083 |
| Diet ~ Income#Subjective norms | 0.030 | 0.020 | 1.492 | 0.136 | 0.030 |
| Diet ~ Gender#Knowledge of climate impact | 0.004 | 0.054 | 0.080 | 0.936 | 0.004 |
| Diet ~ Age#Knowledge of climate impact | -0.015 | 0.024 | -0.625 | 0.532 | -0.015 |
| Diet ~ Income#Knowledge of climate impact | 0.036 | 0.017 | 2.176 | 0.030 | 0.036 |

| | | | | | |
|---|---|---|---|---|---|
| Diet ~ Gender#Barriers to low carbon lifestyle | -0.038 | 0.034 | -1.111 | 0.267 | -0.038 |
| Diet ~ Age#Barriers to low carbon lifestyle | 0.007 | 0.014 | 0.485 | 0.628 | 0.007 |
| Diet ~ Income#Barriers to low carbon lifestyle | -0.005 | 0.009 | -0.546 | 0.585 | -0.005 |
| Transport ~ Attitude | 0.347 | 0.063 | 5.492 | 0.000 | 0.212 |
| Transport ~ Subjective norms | 0.476 | 0.039 | 12.253 | 0.000 | 0.405 |
| Transport ~ Knowledge of climate impact | 0.116 | 0.068 | 1.708 | 0.088 | 0.055 |
| Transport ~ Barriers to low carbon lifestyle | -0.143 | 0.040 | -3.545 | 0.000 | -0.086 |
| Transport ~ Gender | -0.218 | 0.328 | -0.665 | 0.506 | -0.218 |
| Transport ~ Age | 0.445 | 0.144 | 3.081 | 0.002 | 0.445 |
| Transport ~ Income | -0.277 | 0.097 | -2.847 | 0.004 | -0.277 |
| Transport ~ Gender#Attitude | 0.135 | 0.075 | 1.800 | 0.072 | 0.135 |
| Transport ~ Age#Attitude | 0.002 | 0.032 | 0.057 | 0.954 | 0.002 |
| Transport ~ Income#Attitude | 0.028 | 0.021 | 1.334 | 0.182 | 0.028 |
| Transport ~ Gender#Subjective norms | 0.092 | 0.076 | 1.206 | 0.228 | 0.092 |
| Transport ~ Age#Subjective norms | -0.129 | 0.033 | -3.974 | 0.000 | -0.129 |
| Transport ~ Income#Subjective norms | 0.045 | 0.023 | 1.968 | 0.049 | 0.045 |
| Transport ~ Gender#Knowledge of climate impact | -0.019 | 0.059 | -0.328 | 0.743 | -0.019 |
| Transport ~ Age#Knowledge of climate impact | 0.021 | 0.026 | 0.808 | 0.419 | 0.021 |
| Transport ~ Income#Knowledge of climate impact | 0.026 | 0.016 | 1.553 | 0.121 | 0.026 |
| Transport ~ Gender#Barriers to low carbon lifestyle | -0.041 | 0.037 | -1.119 | 0.263 | -0.041 |
| Transport ~ Age#Barriers to low carbon lifestyle | 0.022 | 0.015 | 1.464 | 0.143 | 0.022 |
| Transport ~ Income#Barriers to low carbon lifestyle | 0.003 | 0.010 | 0.329 | 0.742 | 0.003 |
| Shopping behavior ~ Attitude | -0.162 | 0.056 | -2.863 | 0.004 | -0.099 |
| Shopping behavior ~ Subjective norms | 0.486 | 0.035 | 13.701 | 0.000 | 0.413 |
| Shopping behavior ~ Knowledge of climate impact | 0.879 | 0.076 | 11.595 | 0.000 | 0.417 |
| Shopping behavior ~ Barriers to low carbon lifestyle | -0.101 | 0.035 | -2.899 | 0.004 | -0.061 |
| Shopping behavior ~ Gender | -0.443 | 0.302 | -1.469 | 0.142 | -0.443 |
| Shopping behavior ~ Age | 0.245 | 0.131 | 1.866 | 0.062 | 0.245 |
| Shopping behavior ~ Income | -0.224 | 0.096 | -2.337 | 0.019 | -0.224 |
| Shopping behavior ~ Gender#Attitude | 0.170 | 0.069 | 2.478 | 0.013 | 0.170 |
| Shopping behavior ~ Age#Attitude | -0.007 | 0.029 | -0.259 | 0.796 | -0.007 |
| Shopping behavior ~ Income#Attitude | 0.011 | 0.019 | 0.568 | 0.570 | 0.011 |
| Shopping behavior ~ Gender#Subjective norms | 0.019 | 0.066 | 0.286 | 0.775 | 0.019 |
| Shopping behavior ~ Age#Subjective norms | -0.102 | 0.029 | -3.564 | 0.000 | -0.102 |
| Shopping behavior ~ Income#Subjective norms | 0.050 | 0.020 | 2.430 | 0.015 | 0.050 |
| Shopping behavior ~ Gender#Knowledge of climate impact | 0.068 | 0.055 | 1.237 | 0.216 | 0.068 |
| Shopping behavior ~ Age#Knowledge of climate impact | 0.040 | 0.024 | 1.706 | 0.088 | 0.040 |
| Shopping behavior ~ Income#Knowledge of climate impact | 0.025 | 0.016 | 1.595 | 0.111 | 0.025 |
| Shopping behavior ~ Gender#Barriers to low carbon lifestyle | 0.018 | 0.033 | 0.546 | 0.585 | 0.018 |
| Shopping behavior ~ Age#Barriers to low carbon lifestyle | 0.004 | 0.014 | 0.316 | 0.752 | 0.004 |

| | | | | | |
|---|---|---|---|---|---|
| Shopping behavior ~ Income#Barriers to low carbon lifestyle | -0.002 | 0.009 | -0.239 | 0.811 | -0.002 |

# *Appendix IIII*

*Covariances SEM analysis with interactions*

*Table 13: Covariances with indicators of latent variables from SEM analysis with interaction terms*

| Path | Estimate | Std. Err | z-value | P(>\|z\|) | Std. lv. |
|---|---|---|---|---|---|
| Attitude ~ Knowledge of transport | 0.134 | 0.012 | 11.090 | 0.000 | 0.210 |
| Contribution ~ Barrier1 | -0.205 | 0.016 | -13.112 | 0.000 | 0.173 |
| Barrier5 ~ Barrier6 | 0.173 | 0.015 | 11.856 | 0.000 | 0.173 |
| Barrier7 ~ Barrier8 | 0.107 | 0.013 | 8.234 | 0.000 | 0.107 |
| Barrier2 ~ Barrier4 | 0.087 | 0.012 | 7.105 | 0.000 | 0.087 |
| Knowledge of diet ~ Diet | 0.117 | 0.016 | 7.135 | 0.000 | 0.117 |
| Knowledge of transport ~ Transport | 0.086 | 0.017 | 5.038 | 0.000 | 0.086 |
| Knowledge of shopping ~ Shopping behavior | 0.046 | 0.016 | 2.835 | 0.005 | 0.046 |

*Table 14: Covariances latent and observed variables from SEM analysis with interaction terms*

| Path | Estimate | Std. Err | z-value | P(>\|z\|) | Std. lv. |
|---|---|---|---|---|---|
| Attitude ~ Subjective norms | 0.300 | 0.016 | 19.236 | 0.000 | 0.550 |
| Attitude ~ Knowledge of climate impact | 0.162 | 0.011 | 14.689 | 0.000 | 0.516 |
| Attitude ~ Barriers to a low-carbon lifestyle | -0.162 | 0.011 | -15.155 | 0.000 | -0.430 |
| Subjective norms ~ Knowledge of climate impact | 0.207 | 0.012 | 17.371 | 0.000 | 0.489 |
| Subjective norms ~ Barriers to a low-carbon lifestyle | -0.223 | 0.011 | -20.178 | 0.000 | -0.441 |
| Knowledge of climate impact ~ Barriers to a low-carbon lifestyle | -0.092 | 0.007 | -12.765 | 0.000 | -0.314 |
| Diet ~ Transport | 0.202 | 0.014 | 14.525 | 0.000 | 0.202 |
| Diet ~ Shopping behavior | 0.236 | 0.014 | 16.916 | 0.000 | 0.236 |
| Transport ~ Shopping behavior | 0.126 | 0.014 | 8.829 | 0.000 | 0.126 |