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The value of self-determination theory in marketing studies: Insights from the application of PLS-SEM and NCA to anti-food waste apps☆

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ABSTRACT

Self-determination theory (SDT) is a theory of human motivation that highlights the distinction between intrinsic and extrinsic motivations. Recent research has advocated its wider use in marketing studies, suggesting that it has strong predictive accuracy for consumer behaviors, and has proposed arguments about the necessity of both intrinsic and extrinsic motivations for marketing outcomes. However, these statements have not been empirically substantiated. We address this gap by studying the motivations for attitude and intention to use anti-food waste apps. Data from 141 users and 227 non-users of the app "Too Good To Go" are analyzed using partial least squares structural equation modeling (PLS-SEM) and several of its methodological extensions (e.g., multigroup analysis and the cross-validated predictive ability test), and necessary condition analysis (NCA). The findings support the argument that SDT accurately predicts consumer attitudes and behaviors, while NCA provides a nuanced view of the necessity of intrinsic and extrinsic motivations.

1. Introduction

Self-determination theory (SDT) is a theory of human motivation proposed by Deci and Ryan to explain and predict a person's engagement in a specific behavior (Deci & Ryan, 1985; Deci & Ryan, 2000). Since its formalization in the 1980s, SDT has been extensively applied in multiple domains ranging from education to healthcare (Deci & Ryan, 2004; Ryan & Deci, 2017); however, it has received relatively little attention from marketing scholars (Gilal et al., 2019). Gilal et al.'s (2019) in-depth systematic review of the use of SDT in marketing science found that fewer than 50 articles published in relevant journals had explicitly applied SDT.

Gilal et al. (2019) called for wider adoption of SDT by marketing scholars and developed extensive arguments to emphasize SDT's effectiveness to *predict* consumer behaviors. They concluded that SDT is a "promising way to account for different motives when trying to *predict* [emphasis added] behavior through the constructs of intrinsic and extrinsic motivation" (p. 30). Other marketing scholars have proposed similar statements regarding the predictive power of SDT. For example, Arghashi and Yuksel (2022, p. 3) argued that "intrinsic motivation (i.e., inspiration) and extrinsic motivation (i.e., usefulness) *predict* [emphasis added] an array of positive outcomes across AR [augmented reality] contexts." However, to the best of our knowledge, the predictive power of SDT in marketing has not been evaluated. Gilal et al., (2019,p. 38) emphasized that "empirical research is thus needed to investigate whether intrinsic and/or extrinsic motivation has greater influence in *predicting* [emphasis added] various marketing outcomes, such as new product adoption […], customer retention […]" and many others.

Moreover, SDT maintains that intrinsic and extrinsic motivations "are not necessarily additive" (Deci et al., 2017, p. 21), and marketing scholars have recurrently made statements about the necessity of intrinsic and extrinsic motivations to obtain the target outcomes. For example, Gilal et al., (2019,p. 30) indicated that the satisfaction of intrinsic motivations "provide[s] the 'emotional security' that is *required* [emphasis added] to create emotional attachments, thereby leading to subsequent purchases" (i.e., to obtain the outcomes). Similarly, in their study about consumer behavior related to organic food rooted in SDT, Tandon et al., (2020,p. 10) concluded that "motivations (intrinsic and extrinsic) would be the *pre-requisite* and *precipitating factors* [emphasis added] of consumption." However, to the best of our knowledge, SDT studies in the marketing domain have not assessed whether intrinsic and extrinsic motivations are must-have factors for the target marketing

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outcomes. Therefore, a proper evaluation of SDT in terms of both its predictive power and the necessity of intrinsic and extrinsic motivations is required to support its wider use in the marketing domain to predict (and not only explain) consumer attitudes and behaviors.

This study addresses this research gap by combining partial least squares structural equation modeling (PLS-SEM; Cook & Forzani, 2023; Hair et al., 2022; Sarstedt et al., 2022; Sarstedt et al., 2023) and necessary condition analysis (NCA; Dul, 2016; Richter et al., 2020) to assess consumer intention to adopt and continue to use mobile apps against food waste. PLS-SEM has become widely popular in marketing (e.g., Guenther et al., 2023; Sarstedt et al., 2022), management (e.g., Magno et al., 2022; Ringle et al., 2020; Zeng et al., 2021), and several other business disciplines (e.g., Benitez et al., 2020; Cheah et al., 2023b; Ghasemy et al., 2020; Russo & Stol, 2021). Because it enables researchers to perform predictive assessments of models (Hair et al., 2019a; Sharma et al., 2023; Shmueli et al., 2019), PLS-SEM is a valuable method for substantiating arguments that are specifically based on the *predictive* ability of SDT (Gilal et al., 2019). Unlike covariance-based SEM, which focuses on explanation, PLS-SEM takes a causal–predictive perspective that enables the evaluation of the predictive accuracy of structural equation models (Hair et al., 2022) drawing on the $PLS_{predict}$ algorithm (Shmueli et al., 2019) and the cross-validated predictive ability test (CVPAT; Liengaard et al., 2021; Sharma et al., 2023). Additionally, NCA identifies the (levels of) conditions required to obtain a certain outcome. NCA is based on necessity logic, which implies that the absence of a necessary condition cannot be compensated for by other conditions (Richter et al., 2022). Hence, while PLS-SEM is needed to identify the should-have factors, that is, the factors that increase the level of the outcome, NCA indicates the must-have factors, that is, the factors critical for the outcome (Dul et al., 2021; Richter et al., 2020).

The combination of PLS-SEM and NCA provides a rigorous assessment of the proposed research model and actionable insights (Ringle & Sarstedt, 2016), which are particularly relevant in the specific research context addressed in this study. Reducing food waste is a global priority, as acknowledged by Sustainable Development Goal (SDG) 12.3, which aims to, "by 2030, halve per capita global food waste at the retail and consumer levels" (United Nations General Assembly, 2015). The Food and Agriculture Organization estimates that food wastage is responsible for 8–10% of global greenhouse gas emissions (FAO, 2022). Hence, "if food loss and waste were a country, it would be the third biggest source of greenhouse gas emissions" (UNEP, 2021, p. 4). In the food waste hierarchy, practices aimed at reusing food surplus for human consumption are the second-best option after food waste prevention (Papargyropoulou et al., 2014). In this context, anti-food waste apps—the most prominent example being Too Good To Go (TGTG)—are gaining momentum because they enable retailers and consumers to sell and purchase surplus food, respectively (Amaral & Orsato, 2022; Vo-Thanh et al., 2021). The available qualitative evidence indicates that extrinsic (such as economic benefits) and intrinsic motivations (such as the willingness to contribute to environmental sustainability) drive the adoption of anti-food waste apps (Vo-Thanh et al., 2021). However, existing research has not examined whether these motivations accurately predict the intention to adopt or use these apps. Moreover, available research suggests that, after initial enthusiasm, users often tend to reduce or even discontinue the use of anti-food waste apps (Mazzucchelli et al., 2021). However, extant studies have not assessed which motives are necessary conditions for continuance intention and which are desirable but not necessary for continuance intention. Therefore, understanding consumer intention to adopt and continue to use these apps through the combined application of PLS-SEM and NCA is relevant both for theoretical reasons—that is, advancing knowledge about the predictive value of SDT in marketing studies—and because of its practical implications. The findings of this study can provide insights into effectively designing anti-food waste apps to increase adoption by new users and keep current users engaged over time, thus contributing to users' virtuous behaviors toward the reduction of household food waste, which accounts for 61% of worldwide food waste (UNEP, 2021).

Specifically, the model evaluated in this study comprises two intrinsic motivations (green altruism and hedonic motivation) and one extrinsic motivation (utilitarian benefits). The model is assessed using PLS-SEM multigroup analysis (Hair et al., 2018; Henseler et al., 2016), CVPAT (Sharma et al., 2023), and NCA (Hair et al., 2024; Richter et al., 2020) across two groups of respondents, non-users and users of anti-food waste apps, to examine the accuracy of SDT in predicting attitudes and intentions to adopt and continue to use anti-food waste apps.

The following section introduces SDT and discusses the development of the research hypotheses. The methods are then described, followed by a description of the findings and discussion of their implications.

2. Theoretical background and research hypotheses

2.1. Self-determination theory

The SDT is a comprehensive theory of human motivation introduced by Deci and Ryan in the late '70s, formalized in the '80s, and then progressively extended (Deci & Ryan, 2004; Deci & Ryan, 1980b). Today, SDT comprises six mini-theories (for a review see Ryan & Deci, 2019). The cognitive evaluation mini-theory (Deci & Ryan, 1980a) and organismic integration mini-theory (Ryan et al., 1985) were the first two SDT mini-theories developed by Deci and Ryan. Taken together, these two mini-theories posit that human behavior is driven by intrinsic and extrinsic motivations that are integrated into the self (Deci & Ryan, 1985).

Intrinsic motivation is the spontaneous tendency of people to engage in certain activities because of "the interest and enjoyment that accompanies such activities […] without needing external prompts or rewards" (Ryan & Deci, 2019, pp. 117–118). Intrinsically rewarding activities are those that satisfy an individual's basic needs for competence (i.e., the need for self-efficacy or mastery), autonomy (i.e., the need for control over owns actions), and relatedness (the need for belonging) (Ryan & Deci, 2020; Ryan & Deci, 2000a). Extrinsic motivation is conceptualized as "instrumental motivation, and thus concerns all activities aimed at achieving outcomes separable from the behavior itself" (Ryan & Deci, 2019, p. 120). More precisely, the extrinsic motivation defined as "external regulation" drives people to perform certain behaviors to satisfy external pressure or reward contingency (such as monetary gains) (Ryan & Deci, 2000a). Therefore, while interest and enjoyment represent key regulatory processes of internal motivation, instrumentality characterizes extrinsic motivation (Ryan & Deci, 2000a).

SDT has been successfully applied to many domains and decisions, providing extensive evidence that people moved by intrinsic motivations show higher long-term persistence in behavior than those driven by external regulations (Deci & Ryan, 2008b). Moreover, SDT maintains that intrinsic and extrinsic motivations are not additive, meaning that higher extrinsic motivation (e.g., higher monetary rewards) cannot compensate for low intrinsic motivation (Deci et al., 2017; Olafsen et al., 2015). In the marketing domain, SDT has been applied in several research contexts including branding, services, social media, and online shopping (Gilal et al., 2019). Particularly, SDT has been used to examine different marketing outcomes, such as attitudes and behaviors (Sun et al., 2022), including green behaviors (Gilal et al., 2020).

2.2. The food waste context and self-determination theory

Studies on attitudes and behaviors toward food waste (e.g., attitudes toward doggy bags in restaurants) indicate significant effects of both internal drivers, such as moral norms, and external rewards, such as saving money and time (Sirieix et al., 2017; Talwar et al., 2023). The coexistence of intrinsic and extrinsic motivations is also supported by studies that adopt SDT to explore consumer perceptions of anti-food waste technologies (Zaman et al., 2021). Explorative research that

Table 1
Motivations for adopting and using anti-food waste apps.

Values experienced by users of anti-food waste apps (Vo-Thanh et al., 2021)	Motivations for adopting/ using anti-food waste apps in this study	Type of motivation (intrinsic/extrinsic) according to SDT
Social	Green altruism	Intrinsic
Emotional	Hedonic motivation	Intrinsic
Functional	Utilitarian benefits	Extrinsic

specifically addresses the benefits of anti-food waste apps (the focus of this study) has identified three types of values experienced by users and intended as should-have factors for anti-food waste apps use: social, emotional, and functional (Vo-Thanh et al., 2021). Social value originates from contributions to the societal purpose of environmental preservation. Emotional value relates to the enjoyment of living an innovative experience, such as ordering a "surprise" box. Functional value encompasses saving money and time spent cooking (Vo-Thanh et al., 2021). Hence, consistent with this prior work, to evaluate SDT in the context of the adoption and use of anti-food waste apps, this study considers green altruism and hedonic motivation as intrinsic motivations and utilitarian benefits as extrinsic motivations (Table 1).

Green altruism is "the desire of consumers to selflessly benefit others and the environment; it reflects individuals' effective concerns toward society and others' well-being" (Mansoor & Paul, 2022, p. 97). Hedonic motivation is "the fun or pleasure derived from using a technology" (Venkatesh et al., 2012, p. 161). Utilitarian benefits are "benefits that are related to functional aspects," such as money saving and convenience (Sinha & Verma, 2020, p. 2).

However, after initial adoption of anti-food waste platforms, people often tend to discontinue the use of such platforms (Mazzucchelli et al., 2021). We suggest that evaluating the impacts of intrinsic and extrinsic motivations by distinguishing between non-users and users of anti-food waste apps could address both adoption and continuance intentions. The rationale for this distinction is that, while intrinsic and extrinsic motivations may be likely determinants (should-have factors) of both non-users' and users' attitudes and behaviors (Arghashi & Yuksel, 2022; Proksch et al., 2015), differences may exist in the necessity of these motivations across the two groups. In particular, based on SDT (Ryan & Deci, 2000b) and previous insights in the field of green behaviors (Amaral & Orsato, 2022), it may be supposed that extrinsic motivations are necessary for the decision to adopt green behaviors (such as adopting anti-food waste apps), while intrinsic motivations are necessary for continuance intention. This supposition may even be partial, while comprehensive analyses may reveal that both intrinsic and extrinsic motivations are necessary conditions for both nonusers' and users' attitudes and behaviors. SDT is appropriate for addressing this issue because its core tenets acknowledge that intrinsic and extrinsic motivations may have different impacts on short-term behaviors and long-term persistence in behaviors (Deci & Ryan, 2008b). Hence, in this study, we consider short- and long-term behaviors, that is, both non-users' intentions to adopt the app and users' intentions to continue to use the app. Specifically, the next paragraph develops hypotheses on motivations as should-have factors, whereas paragraph 2.4 presents the hypotheses on motivations as must-have factors for attitudes and intentions toward anti-food waste apps.

2.3. Intrinsic and extrinsic motivations as antecedents of attitude and intention

According to SDT, intrinsic and extrinsic motivations indicate a person's representation of the possibility of satisfying their needs. Therefore, they act as antecedents of a person's attitudes and behaviors to satisfy their needs (Deci & Porac, 2015). Literature reviews on the applications of SDT, specifically the cognitive evaluation theory, have reported that the most recurrent outcomes evaluated by scholars were attitudinal measures of liking and behavioral measures related to task performance (Rummel & Feinberg, 1988). The ability to predict outcomes has been central to the applications of SDT (Rummel & Feinberg, 1988), which was in fact intended for both "explicating and predicting human behavior" (Deci & Ryan, 1980a. p. 39), ranging for example from children's actual physical activity (Chatzisarantis et al., 1997) to continued attendance at a 23-month weight-loss program (Williams et al., 1996).

Similarly, available SDT research in the field of marketing has examined the effects of intrinsic and extrinsic motivations on consumer attitudes and behaviors (Gilal et al., 2019; Sun et al., 2022). Some studies have considered the effects of such motivations on either consumer attitudes (e.g., Proksch et al., 2015) or behaviors/behavioral intentions (e.g., Garg et al., 2022), whereas others have simultaneously investigated the effects on both attitudes and behaviors/behavioral intentions using comprehensive models (e.g., Tandon et al., 2020). Despite statements about the ability of SDT to predict consumer attitudes and behaviors (Gilal et al., 2019), marketing applications have focused on explanations rather than predictions (Liengaard et al., 2021), and especially on the associations between intrinsic/extrinsic motivations and marketing outcomes (Gilal et al., 2019). Authors in this field have applied additive logic to address how changes in determinants modify the outcome, meaning that intrinsic and extrinsic motivations are treated as should-have factors (Richter & Hauff, 2022).

Arghashi and Yuksel (2022) reported that intrinsic motivation (i.e., inspiration) positively influenced customer flow and engagement with augmented reality apps. In the context of branded apps, Tran et al. (2022) noted that extrinsic (i.e., utilitarian) motivations were positively associated with users' perceptions of the app's task–service fit and, hence, brand equity. Chiu and Nguyen (2022) found that intrinsic motivations (i.e., the need for competence, autonomy, and relatedness) had positive effects on customers' attitudes toward self-recovery and intention to self-recover after service failure. Sun et al. (2022) observed that intrinsic (i.e., involvement) and extrinsic (i.e., customers' knowledge-sharing intentions) motivations were positively associated with customers' desire to learn about a product, leading to customer satisfaction. Further research revealed that intrinsic and extrinsic motivations had a positive influence on brand attachment (Proksch et al., 2015). Studies on luxury consumption also showed the positive effects of extrinsic and intrinsic motivations on purchase intentions (Shahid & Paul, 2021; Shao et al., 2019). In the context of green consumer behavior, Gilal et al. (2020) emphasized the positive and strong effect of extrinsic motivations.

Most of the available research has examined the effects of (intrinsic and extrinsic) motivations on either attitudes or behavioral outcomes, or evaluated them in separate models and experiments (e.g., Lee & Pounders, 2019). Only a few studies have proposed comprehensive research models to examine how intrinsic and extrinsic motivations affect attitudes and behavioral outcomes. Particularly, Chiu and Nguyen (2022) found that intrinsic motivations directly affected both attitude and behavioral intention, and that attitude partially mediated the relationship between motivations and intentions. Additionally, research on attitudes and buying behaviors toward organic food showed that extrinsic motivation was positively related to attitude and behavior, whereas intrinsic motivation was positively related only to attitude. It was also found that the relationship between attitude and behavior was not significant; hence, attitude did not act as a mediator (Tandon et al., 2020). Therefore, research that simultaneously considered the effects on attitudes and behavioral outcomes provided mixed findings. In summary, most marketing studies that applied SDT supported the positive effects of intrinsic and extrinsic motivations on attitudes and behavior/behavioral intentions, even if they did not assess the predictive power of SDT on such outcomes. Consistent with SDT, in this study, we argue that intrinsic and extrinsic motivations are positively related to the attitude toward anti-food waste apps and the intention to adopt (for non-users)

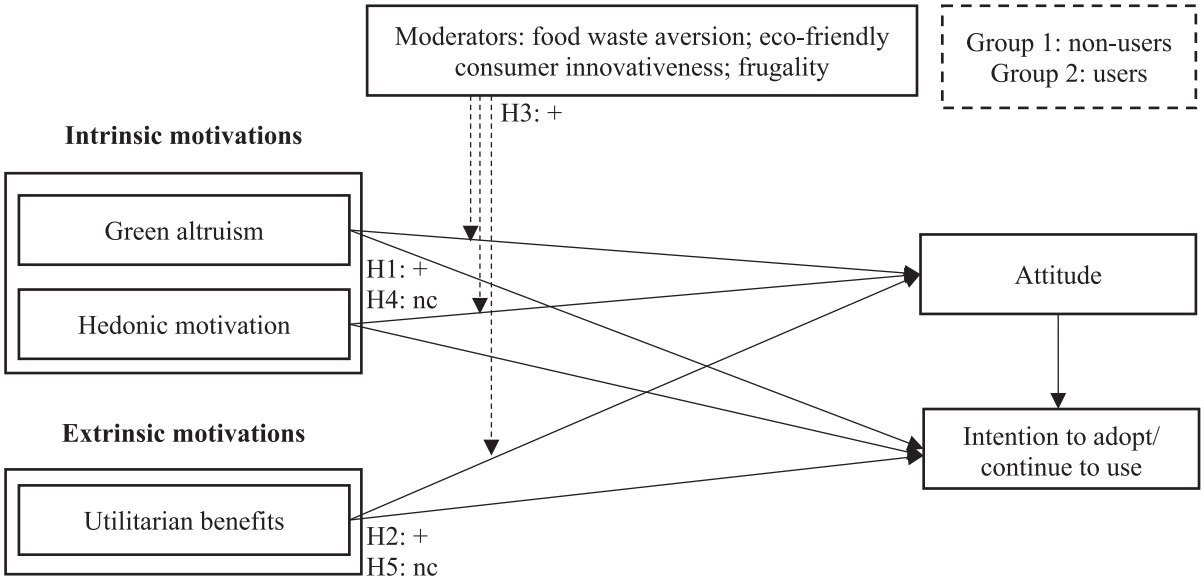

Fig. 1. Research model and hypotheses.

and continue to use (for users) these apps. We specifically assess the predictive accuracy of the suggested model, which includes these motivations (Fig. 1). Specifically, we hypothesize the following:

Hypothesis 1. *Intrinsic motivations* (*green altruism and hedonic motivation*) *are positively related to* (*a*) *attitude toward the app and* (*b*) *intention to adopt or continue using the app*.

Hypothesis 2. *Extrinsic motivations* (*utilitarian benefits*) *are positively related to* (*a*) *attitude toward the app and* (*b*) *intention to adopt or continue using the app*.

Although the primary objective of this study is to evaluate the core tenets of SDT, before moving to necessity logic and NCA (par. 2.4), we complement the assessment of SDT according to additive logic by briefly considering the moderating effects of three variables—food waste aversion, eco-friendly consumer innovativeness, and frugality—that emerged as relevant in prior research on food waste and eco-friendly innovations. Thus, we aim to check the effects of potentially relevant variables in the specific research context in which we applied SDT. In other words, we intend to assess whether the average effect of motivations on attitude depended on the three moderators (Richter & Hauff, 2022). Food waste aversion is a personality trait (van Lin et al., 2023) defined as "attitude of aversion to wasting food" (Raghunathan & Chandrasekaran, 2021, p. 81). Eco-friendly consumer innovativeness is defined as "the consumer's tendency to be knowledgeable about and adopt innovative products and services that are beneficial to the natural environment" (Paparoidamis & Tran, 2019, p. 1551). Frugality refers to "a lifestyle trait reflecting disciplined acquisition and resourcefulness in product and service use" (Lastovicka et al., 1999, p. 96).

While SDT views internal and external motivations processes as universal, researchers, including Deci and Ryan, have suggested that the relationships between motivations and various outcomes might vary in magnitude because of the effects of moderators (Ng et al., 2012). In fact, there may be certain personal traits or cultural beliefs and values that strengthen and weaken the effects of SDT motivations (Vasconcellos et al., 2020). In the specific context of this research, intrinsic and extrinsic motivations reflect a person's representation of the possibility of satisfying their needs (such as protecting the environment, experiencing fun, and saving money and efforts) by adopting or continuing to use anti-food waste apps. According to the main tenets of SDT, these motivations affect attitude toward the app, as stated by H1 and H2. However, these relationships may be stronger for people holding specific personal beliefs. In the related context of organic food purchases, Tandon et al. (2020) argued that a person's environmental values may positively moderate the relationships linking intrinsic and extrinsic motivations and marketing outcomes. van Lin et al. (2023) suggested addressing the effects of moderators such attitude of aversion to wasting food to more deeply understand the effects of motivations (such as price promotions) on consumer decision making regarding food waste behaviors. Paparoidamis & Tran (2019) highlighted a positive interaction effect between motivations (specifically the willingness to be socially visible) and eco-friendly consumer innovativeness on attitude toward eco-innovations. Evers et al. (2018) found that frugality positively moderated the relationship linking motivations and willingness to find alternative methods of product disposal. Hence, we hypothesize the following:

Hypothesis 3. *The relationships between* (*intrinsic and extrinsic*) *motivations and attitudes toward the app are positively moderated by food waste aversion, eco-friendly consumer innovativeness, and frugality*.

2.4. Intrinsic and extrinsic motivations as necessary conditions for attitude and intention

According to the NCA, a factor is necessary if it represents a bottleneck for the outcome (Dul et al., 2023). If this factor is not in place, the outcome will not occur (Richter & Hauff, 2022). Hence, intrinsic (i.e., green altruism and hedonic motivation) and extrinsic (i.e., utilitarian benefits) motivations are necessary conditions if they need to reach certain necessary values to have the intention to adopt or continue to use the app (Dul, 2016). Moreover, the necessary conditions cannot compensate for each other, meaning that the absence of a necessary condition prevents outcomes (Bokrantz & Dul, 2023). If, for example, green altruism is a necessary condition for the outcome and this condition is not satisfied, the intention to adopt or continue to use the app will not be reached, regardless of the levels of hedonic motivation and utilitarian benefits.

Based on their own theoretical reasoning and extensive meta-analysis of SDT applications, Deci and Ryan (2008a, p. 15) emphasized that "the two types of motivation [intrinsic and extrinsic] are not additive, and total motivation is unlikely to be the best predictor of the quality of people's behavior." SDT suggests that intrinsic and self-endorsed extrinsic motivation represent necessary conditions for obtaining the target outcome (e.g., behavior) (Ryan & Deci, 2000a).

Previous research in the marketing domain that has applied SDT has recurrently proposed explicit statements and conclusions about the necessity of extrinsic motivations (e.g., Tran et al., 2022), intrinsic motivations (e.g., Gilal et al., 2019; Kim & Drumwright, 2016), or both (e.g., Sun et al., 2022; Tandon et al., 2020) to obtain a target attitude or behavior. According to Gilal et al., (2019,p. 30), the satisfaction of intrinsic motivations "provide[s] the 'emotional security' that is required to create emotional attachments, thereby leading to subsequent purchases." Concluding their study about branded apps, Tran et al., (2022,p. 18) noted that "utilitarian features [i.e., extrinsic motivation] are critical drivers of task-service fit," and that "to drive this brand equity, branded mobile app customers do not have to experience the highest level of intrinsic motivation […], but rather, they only have to be sufficiently motivated." Moreover, in the managerial recommendations at the end of their study on customer learning, Sun et al., (2022,p. 696) stated that "the willingness to learn [which comprises intrinsic and extrinsic motivations] is a critical premise of effective customer learning." Hence, marketing researchers who apply SDT have repeatedly proposed that intrinsic and/or extrinsic motivations are necessary conditions for target outcomes.

To the best of our knowledge, studies have not yet explicitly evaluated whether intrinsic and extrinsic motivations are necessary conditions for the intention to adopt or continue using anti-food waste apps. Nonetheless, research on consumers' green attitudes and behaviors offers insights into the mechanisms according to which intrinsic and extrinsic motivations are necessary conditions for our study. First, regarding extrinsic motivation, prior research noted that green behaviors (e.g., recycling or purchasing sustainable fashion goods) imply additional costs for consumers in terms of personal efforts or monetary costs, which represent a barrier to sustainable behaviors (Blose et al., 2020). Hence, only if perceived utilitarian gains are higher than perceived additional costs, an individual intends to act in an environmentally friendly manner (Onel & Mukherjee, 2017). In other words, green behaviors such as the use of anti-food waste apps will be present (absent) if utilitarian benefits (i.e., gains outweigh costs) are present (absent). Regarding intrinsic motivations, prior studies suggest that individuals adopt green behavior because they are morally perceived as "the right thing to do" (Carroll, 1991), regardless of extrinsic motivations (Paulraj et al., 2017). Therefore, green behavior is present (absent) if intrinsic benefits are present (absent). Moreover, prior research has explicitly stated that intrinsic motivations are deemed necessary for users' long-term engagement with anti-food waste platforms (Amaral & Orsato, 2022). Therefore, the use of food waste apps will be discontinued if intrinsic motivations are absent (Mazzucchelli et al., 2021). Finally, extrinsic motivations cannot compensate for the absence of intrinsic motivations, because intrinsic motivations are part of a person's self, while extrinsic motivations are not (Schösler et al., 2014). Hence, we hypothesize the following:

Hypothesis 4. *Intrinsic motivations* (*green altruism and hedonic motivation*) *are necessary conditions for* (*a*) *attitude toward the app and* (*b*) *intention to adopt or continue using the app*.

Hypothesis 5. *Extrinsic motivations* (*utilitarian benefits*) *are necessary conditions for* (*a*) *attitude toward the app and* (*b*) *intention to adopt or continue using the app*.

3. Methods

3.1. Research context and sample

Data were collected through an online survey in Italy using convenience sampling. The link to the questionnaire was disseminated through social media posts (Facebook, Twitter, and LinkedIn) via the authors' personal accounts. The questionnaire focused on TGTG, the most prominent example of anti-food waste apps. It was first introduced in 2015 in Denmark and has been operating in Italy since March 2019 (Too Good To Go, 2019). TGTG was created to fight food waste, and it enables consumers to purchase a "magic box" from local restaurants, bakeries, supermarkets etc. that contain surplus, unsold products at a highly discounted price. After purchasing a magic box, the consumer collects it from the store and discovers what it contains (https://toogoodtogo.org/en).

A total of 696 responses were obtained. Respondents were guaranteed anonymity to reduce evaluation apprehension and therefore control for common method bias (Podsakoff et al., 2003). All questions were mandatory, resulting in no missing values. After excluding responses from participants who declared that they did not know about TGTG, the final sample comprised 368 respondents, of whom 141 had used TGTG and 227 knew about but had never used the app. In both groups, approximately two-thirds of the respondents were women, and most were in the 20–39 age group. In 2023, TGTG reported that 5,862,653 people were using the app in Italy (Too Good To Go, 2023), but did not provide any statistics about the demographic profile of its users. Therefore, it is not possible to conclude that our subsample of users is representative of the population of 5,862,653 people using TGTG in Italy. The size of each of the two groups met the minimum requirements to estimate effects between 0.21 and 0.30 at a significance level of 0.95, assuming a power level of 80% (Hair et al., 2022; Kock & Hadaya, 2018).

3.2. Measures and data analysis

All constructs were reflectively measured using multiple-item scales already established in the relevant literature, and were slightly adapted to the research context when necessary. All items were rated on 7-point Likert disagreement–agreement scales. Regarding the independent variables (i.e., motivations), green altruism was measured using four items from Mansoor and Paul (2022), hedonic motivation using three items from Venkatesh et al. (2012) and Talwar et al. (2023), and utilitarian benefits using four items from Sinha and Verma (2020) and Talwar et al. (2023). For the target variables, attitude was assessed using three items from McLean et al. (2020) and intention to adopt/continue to use via two items from Venkatesh et al. (2012). Finally, regarding the moderator variables, we used three items from Lastovicka et al. (1999) for frugality, three items from Raghunathan and Chandrasekaran (2021) for food waste aversion, and five items from Paparoidamis and Tran (2019) for eco-friendly consumer innovativeness. As mentioned previously, the dataset contained no missing values.

Data were analyzed using PLS-SEM and NCA. PLS-SEM enables the evaluation of both the explanatory power and predictive accuracy of a model, thus overcoming the limitations of explanations without prediction (Sarstedt et al., 2023). This strength made PLS-SEM particularly valuable for this research because its main purpose was to assess the predictive power of SDT in the marketing domain, thus substantiating the recurrent statements on this point proposed in the literature (Gilal et al., 2019). PLS-SEM was applied drawing on established procedures (Hair et al., 2022; Sarstedt et al., 2021) and carefully following all recent recommendations (Hair et al., 2019b; Sarstedt et al., 2022; Sarstedt et al., 2023), including those related to the estimation of moderating effects (Becker et al., 2023; Becker et al., 2018). Particularly, the application of CVPAT, which was performed using 10 folds and 10 repetitions as settings, was of primary importance for the assessment of the predictive power of SDT (Hair, 2021; Hair et al., 2021; Liengaard et al., 2021; Sharma et al., 2023). The PLS-SEM algorithm was run using the following settings: 3,000 as the maximum number of iterations, stop criterion of 10^{-7}, and path weighting scheme. Significance was assessed using the bootstrapping routine with 10,000 subsamples and percentile bootstrapping as the confidence interval method (Sarstedt et al., 2023). All these procedures were applied to both groups of respondents (i.e., users and non-users of the TGTG app). Therefore, before performing the multi-group analysis, we executed the measurement invariance of the composite models routine (Cheah et al., 2023a; Hair et al., 2018;

Table 2
Measurement model assessment for non-users and users.

Construct	Item	Outer loadings		Cronbach's alpha		Rho_A		Composite reliability		Average variance extracted (AVE)	
		Non–users	Users	Non–Users	Users	Non–users	Users	Non–users	Users	Non–users	Users
Green altruism (Mansoor and Paul, 2022)[a]	By using TGTG I help saving the planet.	0.917	0.897	0.936	0.940	0.936	0.944	0.954	0.957	0.838	0.848
	By using TGTG I do something positive for the environment.	0.926	0.921								
	By using TGTG I contribute to accomplishing a social mission.	0.891	0.938								
	By using TGTG I am part of the change.	0.927	0.927								
Hedonic motivation (Venkatesh et al., 2012; Talwar et al., 2023)[a]	Using TGTG is fun.	0.849	0.874	0.820	0.862	0.828	0.868	0.892	0.915	0.734	0.782
	TGTG stimulates my curiosity to find out the products contained in the magic box.	0.883	0.896								
	TGTG offers an entertaining experience.	0.837	0.884								
Utilitarian benefits (Sinha and Verma, 2020; Talwar et al., 2023)[a]	TGTG makes it possible to purchase quality food at an accessible price.	0.804	0.806	0.795	0.747	0.804	0.752	0.866	0.840	0.619	0.569
	TGTG allows me to save money.	0.841	0.733								
	Using TGTG I can afford high-quality products at a low price.	0.718	0.768								
	Using TGTG I save time as I do not need to cook for dinner.	0.778	0.705								
Attitude (McLean et al., 2020)[a]	Overall, I feel favorable toward the app.	0.893	0.896	0.860	0.875	0.872	0.885	0.915	0.923	0.782	0.800
	Overall, using the app is a good idea.	0.833	0.870								
	Overall, using the app is a wise idea.	0.924	0.915								
Intention to adopt/ continue to use (Venkatesh et al., 2012)[a]	I am likely to start (continue) using the app in the future.	0.974	0.983	0.943	0.966	0.944	0.968	0.972	0.983	0.946	0.967
	It would be interesting trying (continuing) to use the app.	0.972	0.984								
Frugality (Lastovicka et al., 1999)[a]	I believe in being careful in how I spend my money.	0.879	0.763	0.735	0.759	0.783	0.802	0.848	0.861	0.650	0.675
	I discipline myself to get the most from my money.	0.799	0.899								
	I am willing to wait on a purchase I want so that I can save money.	0.756	0.795								
Food waste aversion (Raghunathan and Chandrasekaran, 2021)[a]	It makes me guilty to waste food when I think of all the poor people who don't get enough to eat.	0.829	0.657	0.745	0.664	0.783	0.696	0.849	0.819	0.652	0.604
	Not wasting food is a family value passed on from generation to generation, which I will pass on to my children as well.	0.837	0.882								
	Growing up, I was taught not to waste food by my parents.	0.754	0.776								
Eco-friendly consumer innovativeness (Paparoidamis and Tran, 2019) [a]	In general, I am among the first in my circle of friends to adopt eco-innovative products.	0.833	0.863	0.910	0.930	0.981	0.947	0.931	0.947	0.729	0.782
	If I hear about new ideas/ products on environmental issues, I am interested to find out more.	0.871	0.870								
	Compared to my friends, I make a lot of consumption choices that are good for the environment.	0.871	0.913								

(*continued on next page*)

Table 2 (*continued*)

Construct	Item	Outer loadings		Cronbach's alpha		Rho_A		Composite reliability		Average variance extracted (AVE)	
		Non–users	Users	Non–Users	Users	Non–users	Users	Non–users	Users	Non–users	Users
	In general, I am the first in my circle of friends to know about eco-friendly consumption issues.	0.875	0.922								
	I know about environmental issues before other people do.	0.816	0.850								

[a] All constructs were modeled as reflective; all items were rated on a 7-point Likert scale, with the extremes being 1 = completely disagree and 7 = completely agree.

Table 3
Discriminant validity: heterotrait–monotrait criterion.

	1	2	3	4	5	6	7	8
1. Green altruism	—	0.627 [0.515; 0.724]	0.802 [0.734; 0.863]	0.653 [0.542; 0.759]	0.573 [0.461; 0.676]	0.152 [0.086; 0.287]	0.275 [0.161; 0.421]	0.279 [0.156; 0.393]
2. Hedonic motivation	0.722 [0.616; 0.809]	—	0.872 [0.795; 0.938]	0.716 [0.594; 0.819]	0.637 [0.514; 0.743]	0.117 [0.081; 0.254]	0.370 [0.239; 0.507]	0.232 [0.114; 0.353]
3. Utilitarian benefits	0.840 [0.761; 0.915]	0.810 [0.695; 0.904]	—	0.768 [0.668; 0.863]	0.727 [0.636; 0.804]	0.179 [0.119; 0.312]	0.337 [0.182; 0.523]	0.286 [0.185; 0.404]
4. Attitude	0.731 [0.630; 0.814]	0.686 [0.544; 0.791]	0.836 [0.719; 0.928]	—	0.799 [0.722; 0.860]	0.126 [0.058; 0.287]	0.282 [0.158; 0.418]	0.207 [0.116; 0.323]
5. Intention to adopt/continue to use	0.625 [0.505; 0.735]	0.625 [0.482; 0.748]	0.843 [0.777; 0.903]	0.801 [0.728; 0.870]	—	0.089 [0.041; 0.157]	0.252 [0.145; 0.379]	0.255 [0.135; 0.376]
6. Frugality	0.393 [0.225; 0.549]	0.198 [0.090; 0.399]	0.363 [0.267; 0.551]	0.240 [0.120; 0.396]	0.120 [0.059; 0.276]	—	0.307 [0.181; 0.452]	0.101 [0.063; 0.235]
7. Food waste aversion	0.355 [0.200; 0.529]	0.338 [0.182; 0.558]	0.317 [0.195; 0.550]	0.285 [0.155; 0.483]	0.274 [0.115; 0.463]	0.465 [0.271; 0.672]	—	0.342 [0.208; 0.500]
8. Eco-friendly consumer innovativeness	0.297 [0.169; 0.426]	0.102 [0.062; 0.245]	0.175 [0.111; 0.330]	0.239 [0.138; 0.370]	0.175 [0.072; 0.308]	0.341 [0.205; 0.478]	0.483 [0.327; 0.640]	—

Note: HTMT values for users are shown below the diagonal, whereas the HTMT values for non-users are shown above the diagonal.

Henseler et al., 2016). The most recent guidelines for the combined use of PLS-SEM and NCA were followed (Richter et al., 2023a; Richter et al., 2023b; Richter et al., 2020). In the execution of NCA, because in most cases the patterns of the observations close to the ceiling lines were irregular, we considered the ceiling envelopment–free disposal hull (CE-FDH) line, which is by definition 100% accurate, and set 10,000 permutations to obtain the significance levels of the effects (Dul, 2020). For outlier analysis, we applied the procedure described by Dul (2021) using the specific function of NCA software 3.3.1 to evaluate potential outliers. This procedure identifies "ceiling zone outliers," namely, cases that affect the size of the ceiling zone (the empty space in the scatter plot), and "scope outliers," namely, cases that affect the scope (the area where cases can appear determined by the minimum and maximum levels of the condition and outcome). Since the NCA effect size is calculated by dividing the ceiling zone by the scope, the removal of outliers can either increase or decrease the effect size (Dul, 2021). The results of the analysis (reported in detail in Appendix A) indicated the existence of a few outliers in each of the two sub-samples. However, they were retained because they could not be related to any sampling or measurement errors (Dul, 2021). All analyses were performed using SmartPLS 4, version 4.0.8.7 (Cheah Jacky et al., 2023c; Ringle et al., 2022).

4. Results

4.1. Measurement model assessment

As all constructs were specified as reflective, we examined indicator reliability, internal consistency reliability, convergent validity, and discriminant validity for both groups (i.e., non-users and users) (Hair et al., 2022; Hair et al., 2019a). Table 2 shows the full list of items, their outer loadings and the values of Cronbach's alpha, composite reliability ρ_c, and exact reliability coefficient ρ_A. For both groups, all outer loadings were higher than 0.70 (except for one item with an outer loading of 0.657), thus confirming indicator reliability (Hair et al., 2019a). Regarding internal consistency reliability, the values of Cronbach's alpha (considered the lower boundary) and composite reliability ρ_c (the upper boundary), as well as the values of the exact reliability coefficient ρ_A, were in the 0.70–0.95 range for both groups, with a few values outside but close to this range. Hence, internal consistency reliability was assessed (Sarstedt et al., 2023). For both groups, the average variance extracted (AVE) was higher than 0.50 for each construct, indicating that convergent validity was met (Hair et al., 2022). Discriminant validity was evaluated by inspecting the heterotrait–monotrait (HTMT) ratios of the correlations and their 95% one-sided bootstrap confidence intervals (Ringle et al., 2023). All HTMT values were below 0.90 for both groups. In a few cases (Table 3), the upper bound of the HTMT value's 95% one-sided bootstrap confidence interval was slightly above 0.90;

Table 4
Compositional invariance: results of the permutation test.

Latent variable	Original correlation	Correlation permutation mean	5.0% quantile	Permutation *p*-value
Green altruism	1.000	1.000	1.000	0.432
Hedonic motivation	1.000	0.999	0.998	0.874
Utilitarian benefits	0.998	0.998	0.994	0.486
Attitude	1.000	1.000	0.999	0.945
Intention to adopt/continue to use	1.000	1.000	1.000	0.091
Eco-friendly consumer innovativeness	0.998	0.994	0.985	0.689
Food waste aversion	0.983	0.967	0.890	0.495
Frugality	0.985	0.895	0.562	0.805

Table 5
Model estimates.

Effects	Non-users				Users			
Direct effects	**Path coefficients**	***p* values**	**95% confidence intervals (two tailed)**	**f^2 effect sizes**	**Path coefficients**	***p* values**	**95% confidence intervals (two tailed)**	**f^2 effect sizes**
Green altruism → Attitude	0.233	0.002***	[0.087; 0.386]	0.055	0.304	0.000***	[0.144; 0.468]	0.089
Hedonic motivation → Attitude	0.285	0.003***	[0.091; 0.469]	0.079	0.178	0.030**	[0.010; 0.328]	0.035
Utilitarian benefits → Attitude	0.281	0.004***	[0.097; 0.482]	0.058	0.351	0.000***	[0.179; 0.520]	0.119
Green altruism → Intention to adopt/ continue to use	0.048	0.477	[−0.078; 0.185]	0.003	−0.010	0.934	[−0.237; 0.236]	0.000
Hedonic motivation → Intention to adopt/ continue to use	0.068	0.454	[−0.107; 0.251]	0.005	0.052	0.577	[−0.123; 0.243]	0.004
Utilitarian benefits → Intention to adopt/ continue to use	0.221	0.008***	[0.062; 0.388]	0.041	0.380	0.000***	[0.228; 0.520]	0.153
Attitude → Intention to adopt/continue to use	0.512	0.000***	[0.329; 0.655]	0.313	0.456	0.000***	[0.284; 0.621]	0.256
Specific indirect effects								
Green altruism → Attitude → Intention to adopt/continue to use	0.119	0.002***	[0.044; 0.198]		0.139	0.004***	[0.057; 0.247]	
Hedonic motivation → Attitude → Intention to adopt/continue to use	0.146	0.008***	[0.044; 0.257]		0.081	0.039**	[0.005; 0.158]	
Utilitarian benefits → Attitude → Intention to adopt/continue to use	0.144	0.010**	[0.046; 0.266]		0.160	0.002***	[0.068; 0.270]	
Moderator analysis								
Eco-friendly consumer innovativeness × Green altruism → Attitude	0.159	0.025**	[0.029; 0.304]	0.028	−0.008	0.923	[−0.195; 0.139]	0.000
Eco-friendly consumer innovativeness × Hedonic motivation → Attitude	−0.092	0.315	[−0.226; 0.124]	0.010	−0.093	0.265	[−0.261; 0.069]	0.010
Eco-friendly consumer innovativeness × Utilitarian benefits → Attitude	−0.066	0.506	[−0.264; 0.123]	0.003	−0.002	0.987	[−0.220; 0.265]	0.000
Frugality × Green altruism → Attitude	0.061	0.501	[−0.123; 0.235]	0.004	0.190	0.068*	[-0.017; 0.396]	0.038
Frugality × Hedonic motivation → Attitude	−0.077	0.389	[−0.258; 0.092]	0.005	−0.174	0.063*	[−0.333; −0.036]	0.039
Frugality × Utilitarian benefits → Attitude	0.042	0.729	[−0.174; 0.298]	0.001	0.022	0.838	[−0.206; 0.230]	0.001
Food waste aversion x Green altruism → Attitude	0.055	0.491	[−0.139; 0.183]	0.003	−0.032	0.775	[−0.216; 0.227]	0.001
Food waste aversion x Hedonic motivation → Attitude	−0.008	0.937	[−0.184; 0.205]	0.000	0.009	0.906	[−0.156; 0.160]	0.000
Food waste aversion x Utilitarian benefits → Attitude	0.055	0.608	[−0.178; 0.242]	0.002	0.103	0.440	[−0.225; 0.296]	0.008

Note: *p < 0.10; **p < 0.05; ***p < 0.01.

however, this was reported for conceptually similar constructs. Hence, discriminant validity was confirmed (Sarstedt et al., 2023).

We also assessed measurement invariance across the two groups of respondents. Measurement invariance must be established before conducting a multi-group analysis to exclude the fact that differences in the estimates are the result of different contents and meanings of the constructs across groups (Hair et al., 2018). We applied the measurement invariance of composite models (MICOM) routine (Henseler et al., 2016). First, configural invariance was established because the indicators, data treatment, and algorithm settings were the same across the two groups. The next step of the MICOM procedure involved assessing compositional invariance, which meant that the correlations between the composite scores of the two groups did not differ from 1. The permutation test (10,000 permutations; Table 4) showed that the null hypothesis for all constructs could not be rejected, thus confirming compositional invariance (Henseler et al., 2016). Therefore, partial measurement invariance was achieved, which allowed for multigroup comparisons (Hair et al., 2018).

4.2. Structural model assessment

First, we evaluated the core model without moderating effects because the main focus of this study was the predictive accuracy of the core SDT model (Becker et al., 2023). This procedure was appropriate because the interaction terms were created using a two-stage approach (Becker et al., 2023; Hair et al., 2022). We checked for collinearity in the structural models of each group. All variance inflation factor values were below the threshold of three, indicating that the estimates were not affected by collinearity (Hult et al., 2018; Sarstedt et al., 2023; Sarstedt et al., 2020). Next, we assessed the significance and relevance of the

Table 6
CVPAT results.

Benchmark	Level of analysis: target construct or overall model	Non-users		Users	
		Average loss difference	*p* value	Average loss difference	*p* value
$CVPAT^{benchmark\_IA}_{construct}$	Attitude	−0.436	0.000	−0.330	0.003
$CVPAT^{benchmark\_IA}_{construct}$	Intention to adopt/ continue to use	−0.843	0.000	−0.644	0.001
$CVPAT^{benchmark\_IA}_{overall}$	Overall model	−0.599	0.000	−0.456	0.001
$CVPAT^{benchmark\_LM}_{construct}$	Attitude	−0.032	0.175	−0.034	0.007
$CVPAT^{benchmark\_LM}_{construct}$	Intention to adopt/ continue to use	−0.088	0.027	−0.128	0.000
$CVPAT^{benchmark\_LM}_{overall}$	Overall model	−0.054	0.023	−0.072	0.000

Note: IA = naïve indicator–average prediction benchmark; LM = conservative linear model prediction benchmark.

Table 7
Importance-performance map analysis results for intention to adopt/continue to use the app.

Construct	Non-users		Users	
	Total effect (β)	Performance	Total effect (β)	Performance
Green altruism	0.167	75.812	0.129	76.009
Hedonic motivation	0.214	75.443	0.133	78.774
Utilitarian benefits	0.365	78.704	0.540	80.063
Attitude	0.512	83.078	0.456	87.605

structural model relationships. The results of the PLS-SEM estimation are presented in Table 5.

For both users and non-users, intrinsic motivations (green altruism and hedonic motivation) were positively related to attitude toward the app[1] but not to intention to adopt/continue to use the app, supporting H1a but rejecting H1b. However, the estimates also indicated that intrinsic motivations had positive indirect effects on intention through attitude. For both groups, extrinsic motivations were positively related to both attitude toward the app and the intention to adopt/continue using the app, supporting both H2a and H2b. Bootstrap multigroup analysis (detailed results are reported in Appendix B) demonstrated that none of the structural relationships differed between the two groups (Henseler et al., 2009). We then assessed the explanatory power of the model. The R^2 values for attitude and intention were 0.492 and 0.575, respectively, for the non-user group and 0.550 and 0.635, respectively, for the user group. Finally, the predictive power of the model was assessed using the $PLS_{predict}$ algorithm with 10 folds and 10 repetitions (Shmueli et al., 2016; Shmueli et al., 2019). Specifically, we applied the CVPAT to evaluate the predictive accuracy of the model against a naïve indicator–averages prediction benchmark and conservative linear model prediction benchmark. The analysis was conducted at both the overall model level and for each of the two target constructs (i.e., attitude and intention to adopt/continue to use) (Liengaard et al., 2021; Sharma et al., 2023). The results for the overall model level (Table 6) showed that the model had a strong predictive validity for both non-users and users. Analysis of the target constructs for the user group highlighted strong predictive validity for both attitude and intention to continue using the app. For the non-user group, the analysis indicated predictive validity for attitude and strong predictive validity for the intention to adopt the app.

Additionally, we conducted an importance-performance analysis (IPMA) to contrast the importance of intrinsic and extrinsic motivations (i.e., their total effects) and their performance in predicting intentions (i.e., their average values on a 0–100 scale) (Damberg et al., 2023; Damberg et al., 2022; Hair et al., 2018; Ringle & Sarstedt, 2016). For both non-users and users, utilitarian benefits have the highest total effects (0.365 and 0.540, respectively), followed by hedonic motivation (0.214 and 0.133, respectively) and green altruism (0.167 and 0.129, respectively) (Table 7). The values of performance for the three constructs across the two groups are included in the 75.443–80.063 range. In each group, utilitarian benefits show slightly higher values (78.704 for non-users and 80.063 for users) than hedonic motivation and green altruism. These findings provide further substantiation of managerial recommendations: managers of anti-food waste apps should prioritize utilitarian benefits (which show by far the highest levels of importance) to improve the intention to adopt and continue using their apps.

The analysis was complemented by evaluating the moderating effects proposed in H3. Overall, the PLS-SEM results (Table 5) revealed that only one of the hypothesized moderating effects was significant at the $p < 0.05$ level. Specifically, among non-users, eco-friendly consumer innovativeness positively moderated the relationship between green altruism and attitude. Additionally, among users, frugality positively moderated the relationship between green altruism and attitude and negatively moderated the relationship between hedonic motivation and attitude, but these effects were significant at the $p < 0.10$ level. Hence, H3 was only partially supported.

PLS-SEM latent variable scores were used for the NCA (descriptive statistics are provided in Table 8). As CE-FDH was used in the analysis, its accuracy was by definition 100%. Table 9 lists the necessity effect sizes d and their significance. An effect size d larger than 0.1 is considered the threshold to identify necessary conditions from a practical perspective (Dul, 2021; Richter et al., 2020). Dul (2016) suggested that $0.1 \leq d < 0.3$ may be considered a medium effect, $0.3 \leq d < 0.5$ a large effect, and $d \geq 0.5$ a very large effect. The findings indicated that intrinsic motivations (green altruism and hedonic motivation) were significant necessary conditions ($p < 0.05$) for attitude and intention in both users and non-users. However, for non-users, green altruism cannot be considered a relevant necessary condition because, even if significant at the $p < 0.01$ level, its effect size d was smaller than 0.1 for both attitude and intention to adopt. In contrast, hedonic motivation showed medium-to-large effects. Therefore, H4 was only partially supported. Extrinsic motivations (utilitarian benefits) were relevant and significant conditions for users and non-users, fully supporting H5.

The bottleneck table provides a detailed view of the ceiling lines, indicating the actual values of the conditions that are necessary for the outcomes (Table 10). For their examination, following the procedure outlined by Richter et al. (2021), we used the 75th percentile to demarcate between low and high outcome levels. Hence, high levels of attitude toward the anti-food waste app can be achieved only with values of utilitarian benefits of at least 3.096 and 3.915 for non-users and users, respectively, on a 7-point scale. Green altruism needs to have scores of at least 2.507 and 2.000 and hedonic motivation needs to have scores of at least 3.355 and 2.521 for non-users and users, respectively. To achieve high levels of intention to adopt/continue to use the anti-food waste app, the following minimum levels of

[1] In the users' group, the path coefficient of the relationship between hedonic motivation and attitude was smaller than 0.20 (i.e., 0.178). In this case, the minimum sample size requirements to estimate the effect at a significance level of 0.95 (power level of 80%) were not satisfied, while they were satisfied for a significance level of 0.90.

Table 8
Descriptive statistics of the latent variables from the PLS-SEM analysis.

Construct	Mean		Standard deviation		Observed minimum		Observed maximum	
	Non-users	Users	Non-users	Users	Non-users	Users	Non-users	Users
Green altruism	5.542	5.561	1.261	1.417	1.000	1.000	7.000	7.000
Hedonic motivation	5.423	5.726	1.113	1.116	1.000	1.303	7.000	7.000
Utilitarian benefits	5.680	5.804	0.985	0.935	1.000	1.464	7.000	7.000
Attitude	5.818	6.256	0.972	0.799	1.000	2.360	7.000	7.000
Intention to adopt/continue to use	5.555	6.161	1.434	1.124	1.000	1.000	7.000	7.000

Table 9
NCA effect sizes.

Group	Construct	Attitude CE-FDH	*p*-value	Intention to adopt/ continue to use CE-FDH	*p*-value
Non-users	Green altruism	0.095	0.001	0.097	0.007
	Hedonic motivation	0.293	0.000	0.329	0.000
	Utilitarian benefits	0.251	0.000	0.414	0.000
	Attitude			0.506	0.000
Users	Green altruism	0.226	0.000	0.154	0.007
	Hedonic motivation	0.234	0.000	0.244	0.000
	Utilitarian benefits	0.338	0.000	0.330	0.000
	Attitude			0.389	0.000

independent variables are necessary for non-users and users: 4.597 and 3.915 for utilitarian benefits, 2.507 and 1.987 for green altruism, and 3.000 and 3.019 for hedonic motivation, respectively. Hence, the bottleneck table shows that users with low levels (about 2.000 on a 7-point scale) of green altruisms can still achieve high levels of attitude and intention to continue to use the anti-food waste app.

5. Implications and conclusions

5.1. Summary of findings

By applying PLS-SEM and some of its methodological extensions to the context of anti-food waste apps, this study is the first to provide evidence of the accuracy of SDT in predicting consumer behaviors. Hence, the findings provide empirical support for the arguments formulated by Gilal et al. (2019), who stated that SDT's predictive ability should encourage marketing scholars to adopt this theory more frequently to predict marketing outcomes. Additionally, the combined use of PLS-SEM and NCA provides a nuanced understanding of the necessity of both intrinsic and extrinsic motivations for consumer attitudes and behaviors. This analysis highlights the fact that not all intrinsic motivations are must-have factors.

In detail, for the outcome variable "attitude" (Table 11), it demonstrated that intrinsic (green altruism and hedonic motivation) and extrinsic (utilitarian benefits) motivations were significant determinants as well as necessary conditions for both users and non-users. The only exception was green altruism for non-users. In this case, the findings suggested that green altruism was a significant antecedent as well as a significant but not relevant necessary condition. Hence, an increase in green altruism will improve attitude; however, this is not a bottleneck for attitude. For the outcome variable "intention to adopt/continue to use" (Table 12), intrinsic motivations (green altruism and hedonic

Table 10
Bottleneck tables for attitude and intention to adopt/continue to use.

Non-users					Users				
Bottleneck for attitude	**Green altruism**	**Hedonic motivation**	**Utilitarian benefits**		**Bottleneck for attitude**	**Green altruism**	**Hedonic motivation**	**Utilitarian benefits**	
0.00%	NN	NN	NN		0.00%	NN	NN	NN	
10.00%	NN	1.903	1.700		10.00%	1.968	1.824	2.875	
20.00%	NN	1.903	1.700		20.00%	1.968	1.824	2.875	
30.00%	NN	1.903	1.700		30.00%	1.968	1.824	2.875	
40.00%	NN	2.622	1.700		40.00%	1.968	1.824	2.875	
50.00%	NN	2.622	1.700		50.00%	1.968	2.521	2.875	
60.00%	NN	2.830	2.913		60.00%	1.968	2.521	2.875	
70.00%	NN	3.258	3.096		70.00%	1.968	2.521	2.875	
75.00%	2.507	3.355	3.096		75.00%	2.000	2.521	3.915	
80.00%	2.507	3.355	3.096		80.00%	3.248	3.981	3.915	
90.00%	3.472	3.986	4.634		90.00%	3.267	4.412	4.723	
100.00%	3.472	3.986	4.634		100.00%	4.976	4.606	5.175	
Bottleneck for intention to adopt	**Green altruism**	**Hedonic motivation**	**Utilitarian benefits**	**Attitude**	**Bottleneck for intention to continue to use**	**Green altruism**	**Hedonic motivation**	**Utilitarian benefits**	**Attitude**
0.00%	NN	NN	NN	NN	0.00%	NN	NN	NN	NN
10.00%	NN	2.830	3.096	3.290	10.00%	NN	NN	NN	NN
20.00%	NN	2.830	3.096	3.661	20.00%	1.968	2.521	2.875	4.000
30.00%	NN	2.830	3.096	3.661	30.00%	1.968	2.521	2.875	4.000
40.00%	NN	2.830	3.096	3.661	40.00%	1.968	2.521	2.875	4.000
50.00%	NN	3.000	3.096	3.661	50.00%	1.968	2.521	2.875	4.000
60.00%	NN	3.000	3.096	4.000	60.00%	1.968	3.019	3.777	4.000
70.00%	2.507	3.000	3.403	4.371	70.00%	1.987	3.019	3.915	5.000
75.00%	2.507	3.000	4.597	4.371	75.00%	1.987	3.019	3.915	5.000
80.00%	2.507	3.000	4.597	4.644	80.00%	1.987	3.019	3.915	5.000
90.00%	2.507	3.258	4.634	5.290	90.00%	2.000	3.806	4.453	5.620
100.00%	3.472	3.258	4.634	5.290	100.00%	3.267	3.806	5.175	5.630

Note: Values for the dependent constructs are shown as percentiles, and the actual values are reported for the conditions. NN = not necessary.

Table 11
Summary of findings for attitude.

Construct	Non-users		Users	
	PLS-SEM results	NCA results	PLS-SEM results	NCA results
Green altruism	Significant determinant	Significant but not relevant necessary condition	Significant determinant	Significant and relevant necessary condition
Hedonic motivation	Significant determinant	Significant and relevant necessary condition	Significant determinant	Significant and relevant necessary condition
Utilitarian benefits	Significant determinant	Significant and relevant necessary condition	Significant determinant	Significant and relevant necessary condition

Table 12
Summary of findings for intention to adopt/continue to use.

Construct	Non-users		Users	
	PLS-SEM results	NCA results	PLS-SEM results	NCA results
Green altruism	Not a significant direct determinant (but a significant indirect effect through attitude)	Significant but not relevant necessary condition	Not a significant direct determinant (but a significant indirect effect through attitude)	Significant and relevant necessary condition
Hedonic motivation	Not a significant direct determinant (but a significant indirect effect through attitude)	Significant and relevant necessary condition	Not a significant direct determinant (but a significant indirect effect through attitude)	Significant and relevant necessary condition
Utilitarian benefits	Significant determinant	Significant and relevant necessary condition	Significant determinant	Significant and relevant necessary condition
Attitude	Significant determinant	Significant and relevant necessary condition	Significant determinant	Significant and relevant necessary condition

Table A1
Analysis of outliers (Users).

Analyzed variables	Outliers	Original effect size	New effect size[a]	Absolute difference[b]	Relative difference[b]	Ceiling zone outlier	Scope outlier
Green altruism - attitude	121	0.23	0.12	−0.11	−47.2	X	X
	4	0.23	0.24	0.01	5.9	X	
	109	0.23	0.23	0.01	2.6	X	
	81	0.23	0.23	0.00	1.1	X	
	78	0.23	0.23	0.00	0.5	X	
	105	0.23	0.23	0.00	0.1	X	
Hedonic motivation - attitude	69	0.23	0.28	0.05	21.3	X	
	46	0.23	0.28	0.05	20.8	X	
	121	0.23	0.24	0.01	3.5	X	X
	93	0.23	0.24	0.00	2.0	X	
	99	0.23	0.24	0.00	1.5	X	
	75	0.23	0.24	0.00	1.3	X	
	4	0.23	0.23	0.00	0.1	X	
Utilitarian benefits - attitude	121	0.34	0.17	−0.17	−49.2	X	X
	43	0.34	0.44	0.10	31.0	X	
	105	0.34	0.35	0.02	5.1	X	
	81	0.34	0.34	0.00	0.5	X	
	58	0.34	0.34	0.00	0.2	X	
Green altruism – intention to continue to use	121	0.15	0.02	−0.13	−84.6	X	X
	100	0.15	0.19	0.03	20.0		X
	4	0.15	0.17	0.02	10.8	X	
	112	0.15	0.16	0.00	1.0	X	
	113	0.15	0.15	0.00	0.2	X	
	70	0.15	0.15	0.00	0.2	X	
Hedonic motivation – intention to continue to use	121	0.24	0.18	−0.06	−24.3	X	X
	100	0.24	0.29	0.05	20.0		X
	46	0.24	0.27	0.03	12.2	X	
	113	0.24	0.27	0.02	9.6	X	
	25	0.24	0.25	0.00	1.3	X	
Utilitarian benefits – intention to continue to use	121	0.33	0.16	−0.17	−52.2	X	X
	100	0.33	0.40	0.07	20.0		X
	43	0.33	0.38	0.05	16.5	X	
	105	0.33	0.34	0.01	4.5	X	
	4	0.33	0.34	0.01	1.7	X	
	21	0.33	0.33	0.00	1.2	X	
	58	0.33	0.33	0.00	0.2	X	
Attitude – intention to continue to use	121	0.39	0.15	−0.24	−62.5	X	X
	100	0.39	0.47	0.08	20.0		X
	20	0.39	0.40	0.01	3.4	X	
	19	0.39	0.39	0.00	0.6	X	
	113	0.39	0.39	0.00	0.5	X	
	3	0.39	0.39	0.00	0.1	X	

[a] Effect size when the outlier is removed.
[b] Difference between the new and original effect sizes.

Table A2
Analysis of outliers (Non-users).

Analyzed variables	Outliers	Original effect size	New effect size[a]	Absolute difference[b]	Relative difference[b]	Ceiling zone outlier	Scope outlier
Green altruism - attitude	7	0.09	0.20	0.10	108.7	X	
	57	0.09	0.12	0.02	23.0	X	
	41	0.09	0.11	0.01	12.7		X
	203	0.09	0.10	0.01	10.5	X	
Hedonic motivation - attitude	41	0.29	0.19	−0.10	−35.4	X	X
	47	0.29	0.32	0.03	10.1	X	
	128	0.29	0.30	0.01	1.8	X	
	65	0.29	0.30	0.00	1.6	X	
	80	0.29	0.30	0.00	0.7	X	
	207	0.29	0.29	0.00	0.6	X	
	147	0.29	0.29	0.00	0.6	X	
	172	0.29	0.29	0.00	0.5	X	
	30	0.29	0.29	0.00	0.3	X	
Utilitarian benefits - attitude	65	0.25	0.36	0.11	42.4	X	
	41	0.25	0.17	−0.08	−31.7	X	X
	199	0.25	0.30	0.04	17.5	X	
	129	0.25	0.26	0.01	4.6	X	
	164	0.25	0.25	0.00	1.0	X	
Green altruism – intention to adopt	7	0.1	0.22	0.13	129.1	X	
	203	0.1	0.11	0.01	14.1	X	
	57	0.1	0.11	0.01	11.1	X	
Hedonic motivation – intention to adopt	41	0.33	0.21	−0.12	−36.2	X	X
	30	0.33	0.35	0.02	6.1	X	
	172	0.33	0.35	0.02	5.4	X	
	147	0.33	0.34	0.01	3.3	X	
Utilitarian benefits – intention to adopt	41	0.41	0.34	−0.08	−18.7	X	X
	199	0.41	0.44	0.03	7.3	X	
	76	0.41	0.42	0.01	1.7	X	
	129	0.41	0.42	0.01	1.4	X	
	164	0.41	0.42	0.00	0.6	X	
	96	0.41	0.41	0.00	0.1	X	
Attitude – intention to adopt	41	0.51	0.44	−0.06	−12.4	X	X
	196	0.51	0.53	0.02	4.7	X	
	201	0.51	0.52	0.01	2.1	X	
	187	0.51	0.51	0.00	1.0	X	
	96	0.51	0.51	0.00	0.8	X	
	30	0.51	0.51	0.00	0.4	X	
	16	0.51	0.51	0.00	0.0	X	

[a] Effect size when the outlier is removed.
[b] Difference between the new and original effect sizes.

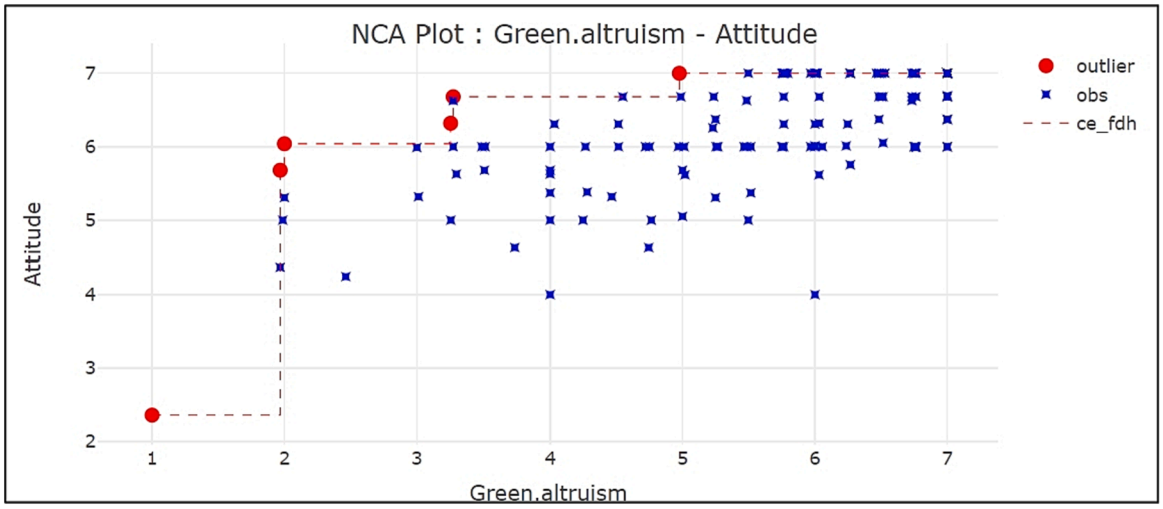

Fig. A1. Scatter plot of outliers: green altruism – attitude (Users). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

motivation) were not direct significant determinants. However, they indirectly affected intentions through attitudes. Extrinsic motivations (utilitarian benefits) were significant (direct and indirect) determinants of intention for both users and non-users. All motivations were also necessary conditions for both users and non-users, except for green altruism for non-users. Similar to what was already found for attitude, green altruism was a significant but not a relevant necessary condition for the intention to adopt the app. Therefore, an increase in green

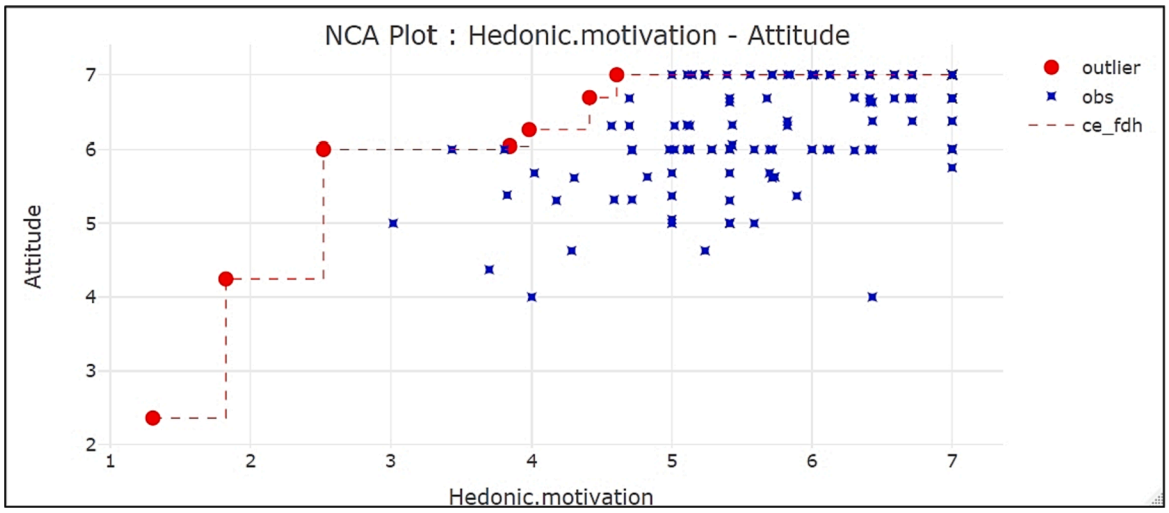

Fig. A2. Scatter plot of outliers: hedonic motivation – attitude (Users). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

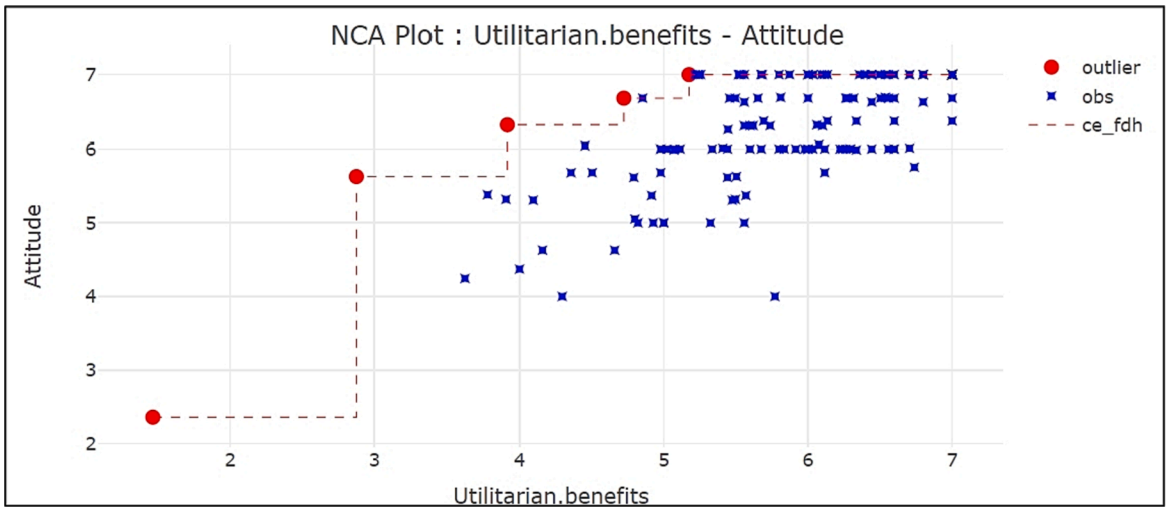

Fig. A3. Scatter plot of outliers: utilitarian benefits – attitude (Users). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

altruism increases intentions, but this is not a bottleneck for intention.

5.2. Theoretical implications

This study aimed to address the relevant gap in the predictive power of SDT and the necessity of intrinsic and extrinsic motivations for consumer attitudes and behaviors. Available research advocating the wider use of SDT in marketing studies emphasized the predictive accuracy of this theory in the marketing domain, but it did not provide evidence to substantiate such statements (Gilal et al., 2019). This lack was remarkable given that SDT was originally explicitly developed for both "explicating and predicting human behavior" (Deci & Ryan, 1980a. p. 39), but marketing studies have emphasized its use for explanations and overlookeed predictions. Hence, the extent to which SDT was useful in predicting actual consumer attitudes and behaviors was not clear. Through an analysis of the context of the adoption and use of anti-food waste apps, this study filled this gap by offering three main theoretical implications.

First, through the application of PLS-SEM advanced techniques, this study confirmed that SDT has strong predictive accuracy. Specifically, SDT proved accurate in predicting attitudes, intention to adopt, and intention to continue using new services, such as anti-food waste apps. Moreover, by combining PLS-SEM and NCA, this study provided evidence that intrinsic and extrinsic motivations were necessary for the attitudes and intentions to adopt or continue to use anti-food waste apps. However, it also offered a more nuanced view, indicating that although significant, not all intrinsic motivations were relevant necessary conditions. Particularly, for non-users, green altruism was not a relevant necessary condition for their attitude toward the app or their intention to adopt it. The findings corroborated the validity of one of the main SDT tenets in the marketing context, according to which intrinsic and extrinsic motivations are not additive (Deci & Ryan, 2008a). Hence, these results corroborate research on SDT (e.g., Gilal et al., 2019; Tandon et al., 2020) suggesting, but not demonstrating, the necessity of intrinsic and/or extrinsic motivations to obtain target customer attitudes and behaviors. Consequently, by evaluating the significance and relevance of the conditions, this study showed that although statistically significant, not all intrinsic motivations were relevant as necessary conditions, thus confirming the intuition of a few previous studies in the marketing domain (Tran et al., 2022).

Second, from the methods perspective, the findings of this research confirmed the great potential of PLS-SEM and its recent methodological

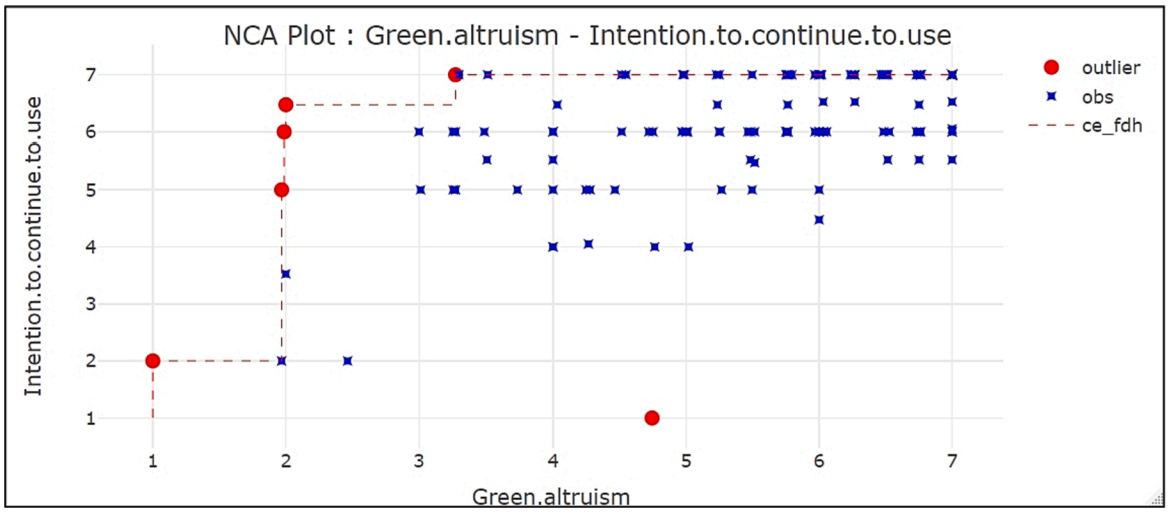

Fig. A4. Scatter plot of outliers: green altruism – intention to continue to use (Users). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

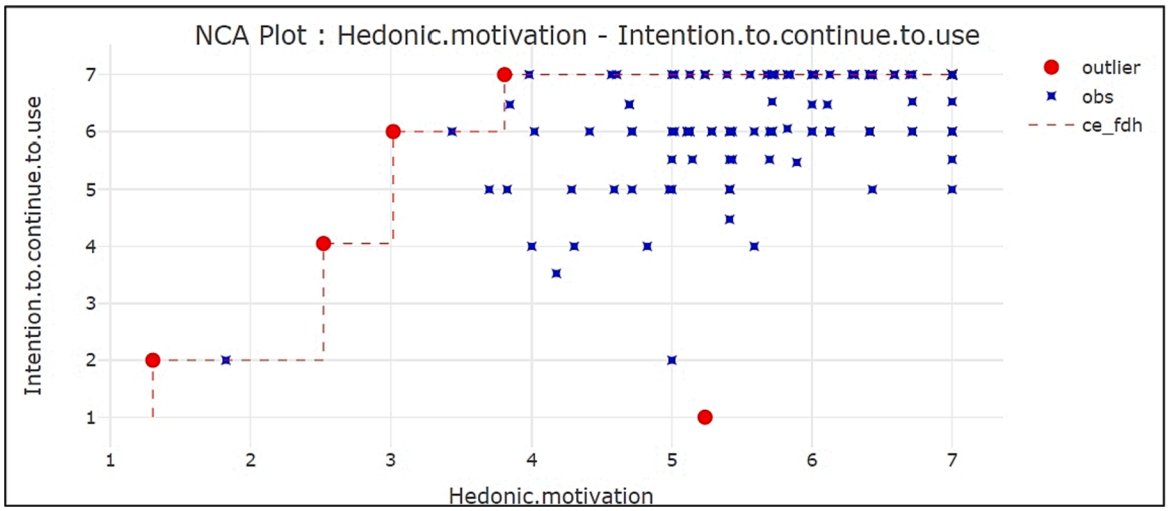

Fig. A5. Scatter plot of outliers: hedonic motivation – intention to continue to use (Users). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

extensions (e.g., CVPAT, multigroup analysis, and IPMA) to shed new light on the extendibility of theories to the marketing field and assess their predictive accuracy in this domain. The results highlighted the benefits of the combined use of PLS-SEM and NCA (Richter et al., 2023a; Richter et al., 2023b; Richter et al., 2020). This analysis enabled the identification of should-have and must-have factors, revealing that, while all intrinsic and extrinsic motivations were should-have factors, not all were relevant must-have factors for the outcomes. Such findings not only provide an additional theoretical contribution to SDT in marketing studies, but also offer meaningful insights for managerial recommendations.

Third, the findings of this study contributed to advancing knowledge on attitudes and behaviors toward anti-food waste initiatives (Sirieix et al., 2017; Talwar et al., 2023), specifically on the adoption of anti-food waste apps. Particularly, the results clarify that intrinsic and extrinsic motivations are important factors in explaining and predicting a person's intention to adopt and continue using anti-food waste apps. Additionally, the findings highlighted that green altruism is not a relevant necessary condition for the adoption of anti-food waste apps. These findings corroborate the results of exploratory research that identified three types of values—social, emotional, and functional—experienced by users of anti-food waste apps (Vo-Thanh et al., 2021). However, our results clarify both the importance and necessity of the motivations related to these values. This study also provides insights into the phenomenon of discontinuing the use of anti-food waste apps reported in previous research (Mazzucchelli et al., 2021). It highlighted that satisfaction with both intrinsic and extrinsic motivations is required for the intention to continue using anti-food waste apps over time. Nonetheless, users of anti-food waste apps with low levels of green altruisms can still achieve high levels of intention to continue to use them. From a wider perspective, the findings of this study contribute to research on SDGs, particularly SDG 12.3, which aimed to halve per capita global food waste by 2030 (United Nations General Assembly, 2015). The results showed how SDT can be used to predict people's intentions to engage in anti-food waste programs and to remain engaged over time. They also allowed us to distinguish between the nice-to-have and must-have factors for these outcomes. Anti-food waste apps provide insights into how these programs can create value for users, thus remaining relevant over time (Amaral & Orsato, 2022).

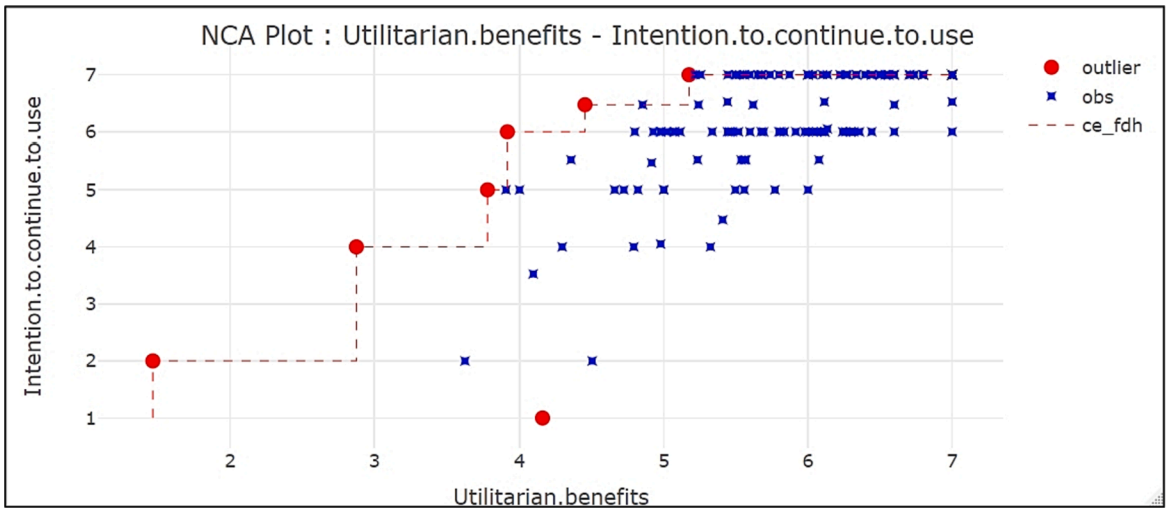

Fig. A6. Scatter plot of outliers: utilitarian benefits – intention to continue to use (Users). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

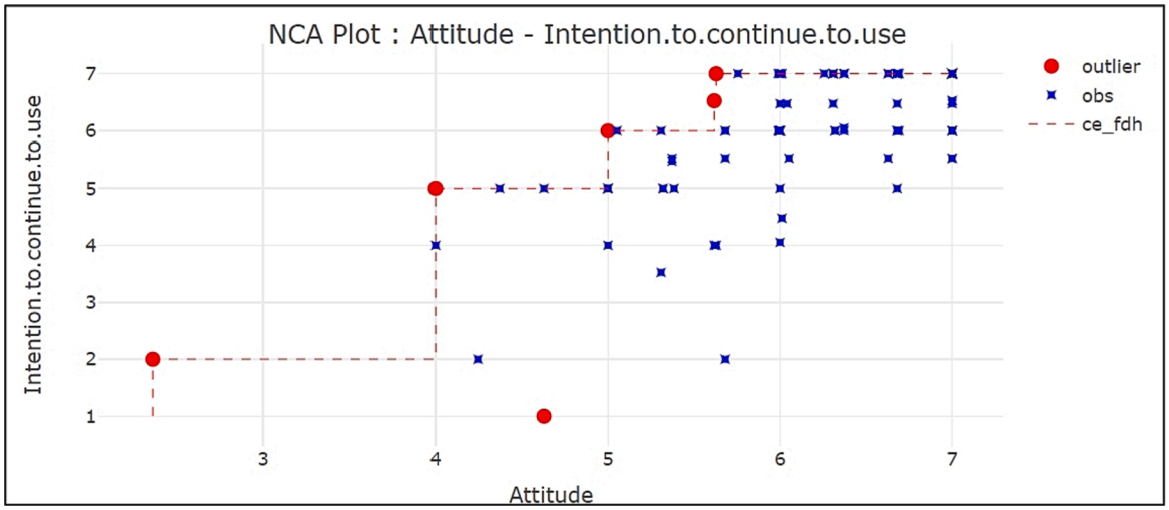

Fig. A7. Scatter plot of outliers: attitude – intention to continue to use (Users). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

5.3. Managerial implications

The combined use of PLS-SEM and NCA made it possible to derive actionable insights into the design and functioning of anti-food waste apps. Overall, features that satisfy both intrinsic and extrinsic motivations are important for the app's success. However, the findings of this study provide more precise insights. First, when targeting non-users, anti-food waste apps should appeal to hedonic motivations, emphasizing enjoyment and fun (e.g., the curiosity to discover the products contained in the magic box in the case of TGTG) and utilitarian motivations (e.g., money and time savings). However, green altruism is not a priority, because it does not represent a bottleneck for developing positive attitudes toward the app and adoption intention. That is, feeling a part of a social movement to save the environment is not a necessary condition for the development of non-users' intentions to adopt the app. In contrast, when targeting current users, anti-food waste apps should appeal to green altruism together with hedonic motivations and utilitarian benefits to encourage users to continue using the app. However, as high levels of continuance intention can be achieved even with low levels of green altruism, investments to improve the appeal to green altruism among users should be allocated judiciously. The IPMA also indicates that beyond representing a necessary condition for adoption and use continuance, utilitarian benefits have the strongest total effect on these outcomes. Hence, managers of anti-food waste apps should prioritize utilitarian benefits to increase the intention to adopt and continue using their apps. By relying on bottleneck tables, anti-food waste app owners could also make specific choices about the level of investment in a specific app's features based on the level of outcomes they intend to obtain.

From a wider perspective, the findings of this study may offer useful insights for private and public institutions to design anti-food waste programs to meet SDG 12.3. Overall, these findings indicate that such programs should satisfy both intrinsic and extrinsic motivations. However, they also suggest that green altruism is not a relevant necessary condition for people's intention to engage in such programs. Hence, utilitarian benefits (such as money savings and/or reduced effort) and hedonic benefits (such as enjoyment) should be prioritized to attract non-users. However, for users, all intrinsic and extrinsic benefits are needed to keep people engaged over time.

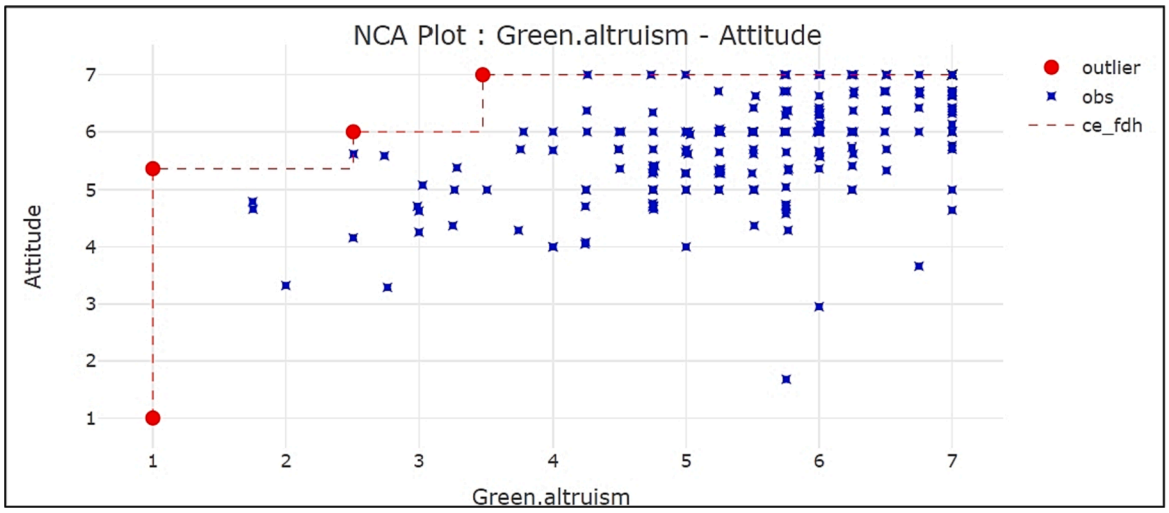

Fig. A8. Scatter plot of outliers: green altruism – attitude (Non-users). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

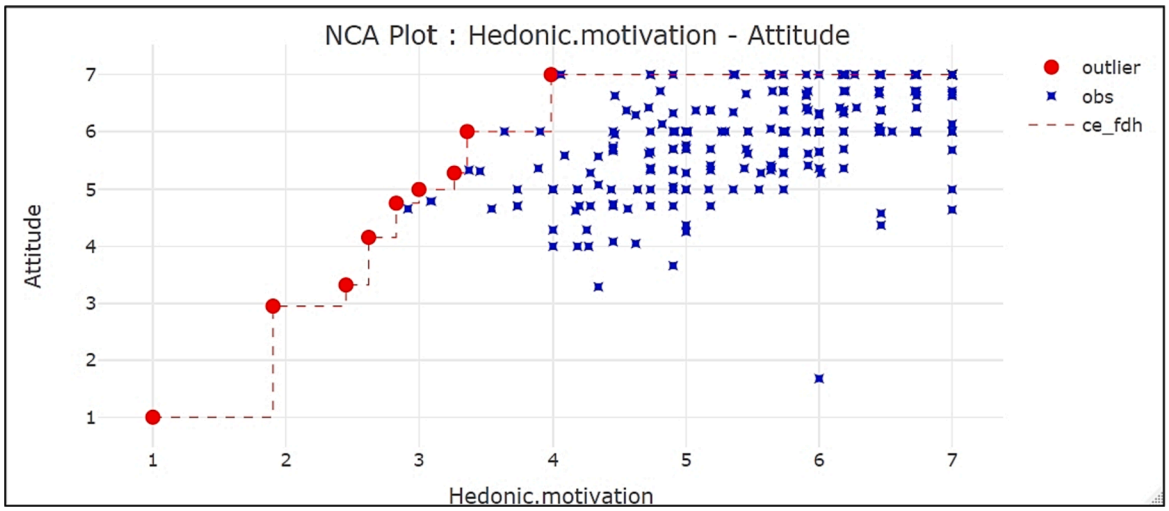

Fig. A9. Scatter plot of outliers: hedonic motivation – attitude (Non-users). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

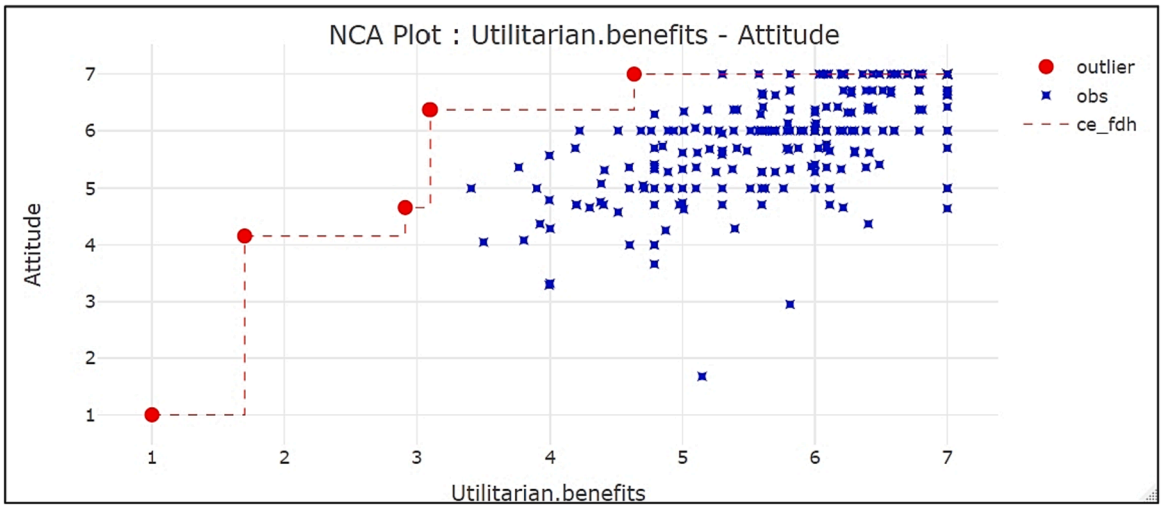

Fig. A10. Scatter plot of outliers: utilitarian benefits – attitude (Non-users). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

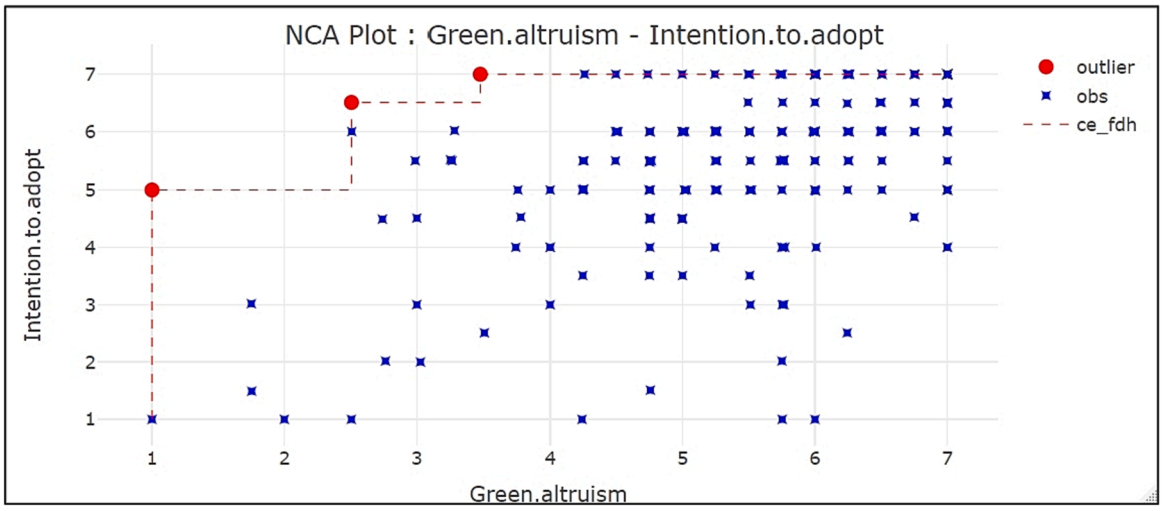

Fig. A11. Scatter plot of outliers: green altruism – intention to adopt (Non-users). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

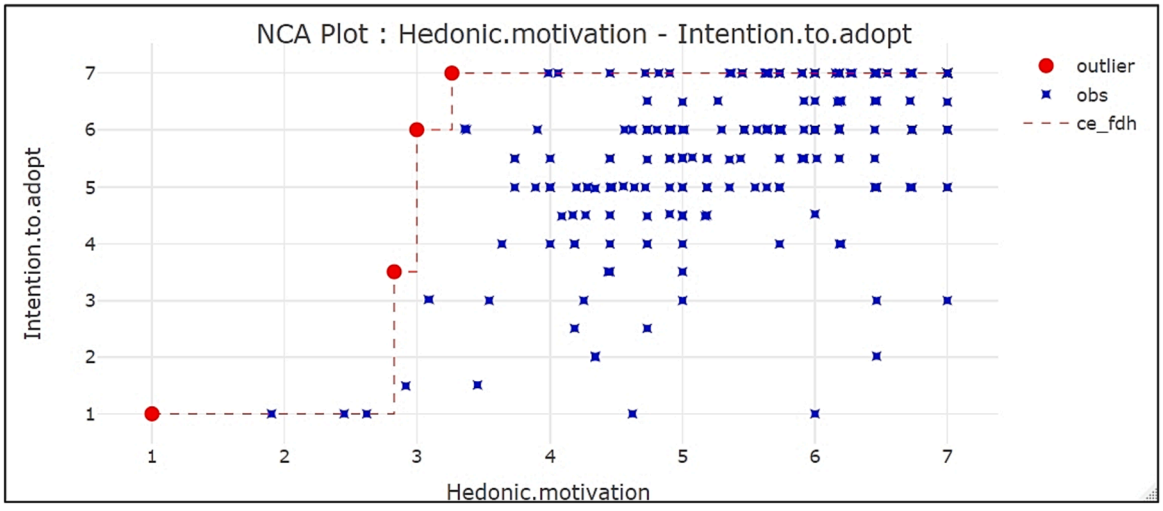

Fig. A12. Scatter plot of outliers: hedonic motivation – intention to adopt (Non-users). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

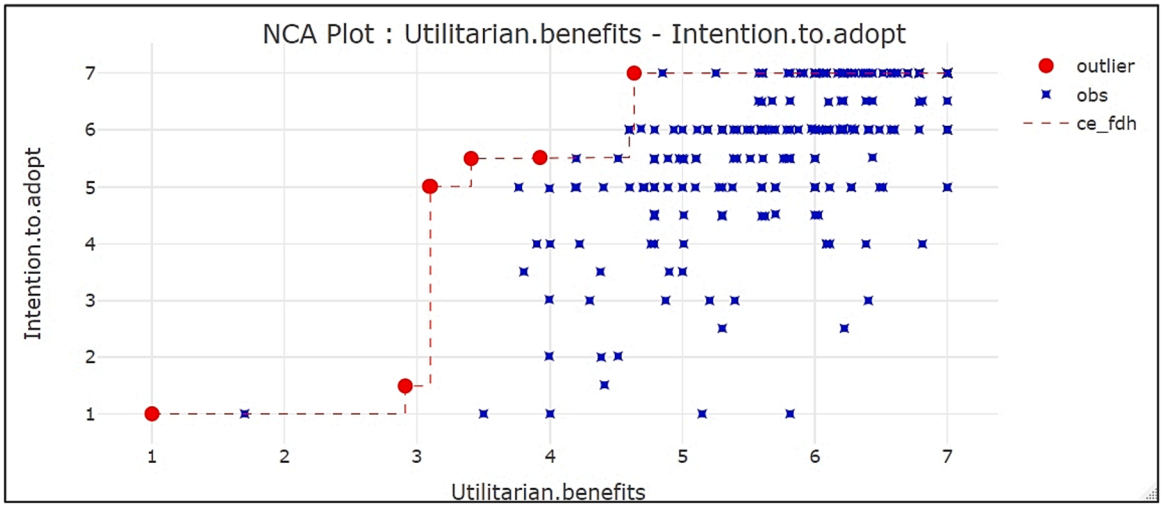

Fig. A13. Scatter plot of outliers: utilitarian benefits – intention to adopt (Non-users). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

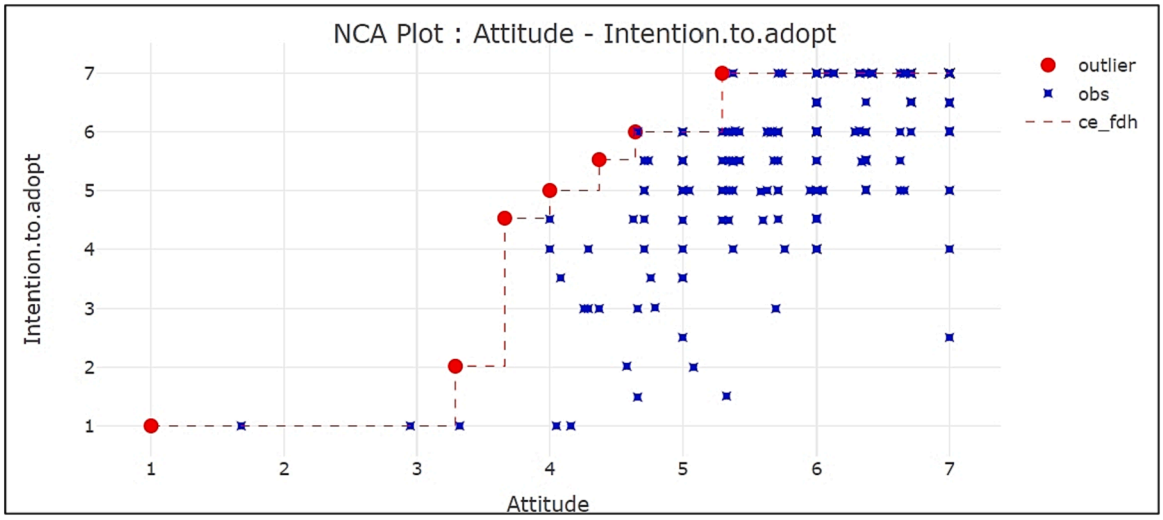

Fig. A14. Scatter plot of outliers: attitude – intention to adopt (Non-users). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table B1
Results of bootstrap multigroup analysis.

Effects	Difference (Non-users - Users)	1-tailed *p* value	2-tailed *p* value
Direct effects			
Green altruism → Attitude	−0.071	0.737	0.527
Hedonic motivation → Attitude	0.108	0.200	0.401
Utilitarian benefits → Attitude	−0.07	0.704	0.592
Green altruism → Intention to adopt/ continue to use	0.058	0.331	0.662
Hedonic motivation → Intention to adopt/continue to use	0.016	0.451	0.901
Utilitarian benefits → Intention to adopt/continue to use	−0.159	0.922	0.157
Attitude → Intention to adopt/ continue to use	0.056	0.317	0.634
Specific indirect effects			
Green altruism → Attitude → Intention to adopt/continue to use	−0.019	0.613	0.774
Hedonic motivation → Attitude → Intention to adopt/continue to use	0.065	0.168	0.335
Utilitarian benefits → Attitude → Intention to adopt/continue to use	−0.016	0.587	0.827
Moderator analysis			
Eco-friendly consumer innovativeness × Green altruism → Attitude	0.167	0.059	0.117
Eco-friendly consumer innovativeness × Hedonic motivation → Attitude	0.000	0.515	0.970
Eco-friendly consumer innovativeness × Utilitarian benefits → Attitude	−0.064	0.648	0.704
Frugality × Green altruism → Attitude	−0.129	0.831	0.338
Frugality × Hedonic motivation → Attitude	0.097	0.221	0.441
Frugality × Utilitarian benefits → Attitude	0.019	0.461	0.922
Food waste aversion x Green altruism → Attitude	0.087	0.256	0.512
Food waste aversion x Hedonic motivation → Attitude	−0.017	0.558	0.884
Food waste aversion x Utilitarian benefits → Attitude	−0.048	0.621	0.757

5.4. Limitations and future research

This study has several limitations that should be considered when interpreting the findings. The empirical study focused on one specific app (TGTG) and relied on data collected from only one country through convenience sampling, suggesting caution in generalizing the findings. Additionally, users' and above all non-users' attitudes and intentions toward the app may have been significantly influenced by the number of merchants using the app in their local areas. In fact, TGTG is mostly active in specific urban areas, and non-users may have been discouraged from developing the intention to adopt the app if they knew that there were not enough merchants in their area. Therefore, replicating this study using samples from different research contexts (e.g., different countries and different food waste apps) and considering additional variables (e.g., the number of available merchants using the app in the respondent's local area) could provide valuable evidence to increase the generalizability of our findings. Future studies may use the same method to evaluate the accuracy of SDT in predicting the outcomes of anti-food waste programs other than the introduction of anti-food waste apps, thus offering additional insights to private and public institutions working to meet SDG 12.3. Future research could also use PLS-SEM to assess the accuracy of SDT in predicting a wide array of other marketing outcomes, such as customer engagement, satisfaction, loyalty, and value co-creation behaviors.

CRediT authorship contribution statement

Fabio Cassia: Conceptualization, Data curation, Methodology, Project administration and Software, Formal analysis, Writing – original draft, Writing – review & editing **Francesca Magno:** Conceptualization, Data curation, Methodology, Project administration and Software, Formal analysis, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A

See Tables A1, A2 Figs A1–A14

Appendix B

Table B1

References

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