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Exploring behavioral motivations as drivers for the adoption of bio-economy innovations

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Abstract

For the past centuries, fossil resources served the German economy as the basis for numerous technological innovations facilitating continuous economic growth and prosperity. However, global challenges of the 21st century such as climate change and depleting resources increasingly uncover the unintended consequences of a fossil-based economy for the social and natural system. One promising strategy to solve these problems is presented by the bio-economy concept which aims to replace fossil resources by bio-based materials stemming from plants, animals, microorganisms and biological waste streams. In this vein, this innovative concept exposes the agri-food sector to a whole set of novel value-added processes, products and services (e.g. bio-energy or bio-based plastics). The success of these innovations ultimately depends on value chain actors' behavioral motivations to adopt them. However, many economic regions still do not fully take advantage of bio-economy innovations which is why it is critical to understand the factors that drive actors in the agri-food value chain to adopt these innovations. Hence, this thesis explores how farmers' and consumers' adoption decisions are affected by their internal behavioral motivations such as their values, beliefs and norms. Moreover, this thesis uses insights from behavioral economics to test nudging strategies to foster the adoption of bio-economy innovations.

In order to achieve these objectives, this thesis conducts three empirical studies. The first study assesses the effect of behavioral motivations on farmers' interest in the adoption of bio-economy practices, using the case of the utilization of horticultural by-products. Therefore, a survey with German fruit and vegetable farmers (N = 96) has been carried out and data have been analyzed in a Structural Equation Model. Findings suggest that pro-environmental values, beliefs and norms are relevant to predict farmers' interest in bio-economy practices. Results further indicate that an ecological worldview is potentially relevant for farmers' perception of contextual conditions aimed to foster the bio-economy.

The second study explores systems thinking as a behavioral motivation for consumer intention to buy bio-based products. The study draws upon an online survey (N = 446) with a between-subject design to situate consumers' level of systems thinking in relation to their altruistic values, an ecological worldview, beliefs and norms as well as intention to buy bio-based products. This study provides empirical evidence that a behavioral task in which consumers reflect on the consequences of their own consumption behavior is successful in activating a systems thinking perspective which, in turn, affects their intention to purchase bio-based products. Moreover, the relationship between systems thinking and purchase intention seems to be mediated by consumers' problem awareness, outcome efficacy and personal norms.

The third study investigates the effectiveness of green nudges to increase consumer willingness to pay for bio-based products, using the case of bio-based plastic packaging. The study uses a discrete choice experiment (N = 1019) with a between-subject-design to activate consumer pro-environmental values, worldviews, beliefs and norms by providing them with nature pictures, reflection questions, information and social proof, respectively. Results indicate that the strongest effects are generated when the nudging strategy matches the characteristic of consumers' cognitive style.

The scientific and practical contributions of this thesis are multifold. From a scientific perspective, it extends the widely used value-beliefs-norms theory by contextual factors to understand farmers' interest in bio-economy practices and integrates systems thinking into the seminal norm-activation model to understand consumer intention to purchase bio-based products. In addition, it theoretically explores the interaction between green nudges and individual cognitive styles. Methodologically, this thesis develops and tests a treatment to activate systems thinking. Besides, it adds to existing empirical research by providing evidence for the role of systems thinking, the value-beliefs-norms theory and green nudges in the context of the bio-economy.

This thesis, moreover, generates important practical implications for policymakers and industry representatives. In this vein, it presents scientifically sound strategies to speed up the diffusion of innovations, to influence the outcome of innovation-decisions and it shows which values and cognitive paradigms are relevant in the context of the bio-economy. For example, consumers' willingness to pay a price premium for bio-based plastic packaging might encourage companies to invest in this type of packaging. However, as the transition towards a bio-based economy rather depends on changing the underlying beliefs of the value chain actors, this thesis also provides insights about internal values and cognitive paradigms that need to be taught in schools and universities to generate a cultural transition starting with the young generations.

Zusammenfassung

Im letzten Jahrhundert dienten fossile Ressourcen als Grundlage zahlreicher technologischer Innovationen, die die deutsche Wirtschaft zu kontinuierlichem Wachstum und Wohlstand verholfen haben. Globale Probleme des 21. Jahrhundert, wie zum Beispiel der Klimawandel und das Erschöpfen fossiler Rohstoffe, zeigen allerdings immer mehr die ungewollten Konsequenzen einer fossil-basierten Wirtschaft für die Gesellschaft und Umwelt auf. Eine vielversprechende Strategie, um diese Probleme zu lösen stellt das Bioökonomie-Konzept dar, das darauf abzielt, fossile Ressourcen durch bio-basierte Materialien zu ersetzen. Diese Materialien werden aus Pflanzen, Tieren, Mikroorganismen und biologischem Abfall gewonnen. Das innovative Bioökonomie-Konzept stellt für die Agrar- und Ernährungswirtschaft eine ganze Reihe neuer Prozesse, Produkte und Dienstleistungen bereit (z.B. Bioenergie oder bio-basiertes Plastik). Der Erfolg der Bioökonomie hängt davon ab, ob die Akteure entlang der Wertschöpfungskette motiviert sind, diese Innovationen zu adoptieren. Da das volle wirtschaftliche Potential der Bioökonomie noch nicht ausgenutzt wird, ist es wichtig zu verstehen, welche Faktoren diese Akteure darin beeinflussen Innovationen im Kontext der Bioökonomie zu übernehmen. Daher untersucht diese Arbeit, inwiefern die Adoptionsentscheidung von Konsumenten und Landwirten durch deren innere Verhaltensmotivationen beeinflusst wird, wie z.B. durch ihre Werte, Glaubenssätze und Normen. Zudem nutzt diese Dissertation Erkenntnisse aus der Verhaltensökonomie, um zu testen, ob Nudging-Strategien die Akzeptanz von bioökonomischen Innovationen fördern.

Um das Ziel dieser Arbeit zu erreichen, werden drei empirische Studien durchgeführt. Die erste Studie untersucht den Einfluss innerer Verhaltensmotivationen auf das Interesse von Landwirten, landwirtschaftliche Nebenprodukte für die Weiterverarbeitung in der Bioökonomie bereitzustellen. Dafür wurde eine Umfrage mit deutschen Obst- und Gemüsebauern (N = 96) durchgeführt und anschließend in einem Strukturgleichungsmodell analysiert. Die Ergebnisse legen nahe, dass umweltbewusste Werte, Glaubenssätze und Normen relevant sind, um das Interesse von Landwirten an bioökonomischen Praktiken vorherzusagen. Die Ergebnisse zeigen weiterhin, dass ein ökologisches Weltbild potentiell relevant dafür ist, wie Landwirte die exteren Bedingungen für den Wandel zu einer Bioökonomie wahrnehmen.

Die zweite Studie erforscht den Einfluss einer systemischen Denkweise auf die Konsumentenakzeptanz von biobasierten Produkten. Die Studie nutzt ein Online-Experiment (N = 446) mit einem between-subject Design, um zu verstehen wie systemisches Denken mit altruistischen Werten, einem ökologischen Weltbild, ökologischen Glaubenssätzen und Normen, sowie der Intention biobasierte Produkte zu kaufen, zusammenhängt. Die Ergebnisse signalisieren, dass eine Intervention, die Konsumenten dazu anhält über ihr Konsumverhalten und dessen Konsequenzen nachzudenken, eine systemische Denkweise triggert, die wiederum

die Intention stärkt, bio-basierte Produkte zu kaufen. Außerdem zeigen die Ergebnisse, dass der Zusammenhang zwischen systemischem Denken und der Kaufintention durch die Variablen Problembewusstsein, wahrgenommene Ergebniswirksamkeit und die persönlichen Normen des Konsumenten erklärt werden kann.

Die dritte Studie untersucht die Effektivität von Nudging-Strategien zur Steigerung der Zahlungsbereitschaft von Konsumenten für bio-basierte Verpackungen. Die Studie nutzt ein diskretes Entscheidungsexperiment (N = 1019) mit einem between-subject Design. Dabei werden den Konsumenten Naturbilder, Reflexionsfragen, Videos oder normative Informationen dargeboten, um umweltbewusste Werte, Weltbilder, Glaubenssätze und Normen zu aktivieren. Die Ergebnisse zeigen, dass die stärksten Effekte erzielt werden, wenn die Nudging-Strategie zum kognitiven Entscheidungsstil der Konsumenten passt.

Der wissenschaftliche und praktische Nutzen der Ergebnisse ist vielfältig. Aus wissenschaftlicher Perspektive erweitert die Arbeit die Value-Belief-Norm Theorie um kontextuelle Faktoren zur Vorhersage des Interesses von Landwirten an bioökonomischen Prozessen. Außerdem integriert sie die Variable des systemischen Denkens in das Norm-Activation Modell, um die Intention biobasierte Produkte zu kaufen besser zu verstehen. Darüber hinaus erforscht die Arbeit den Zusammenhang zwischen Nudging-Strategien und kognitiven Entscheidungsstilen. Aus methodischer Perspektive entwickelt und testet diese Arbeit eine Intervention zur Aktivierung einer systemischen Denkweise. Außerdem liefert die Arbeit empirische Beweise für die Rolle des systemischen Denkens, der Value-Belief-Norm Theorie und Nudging-Strategien im Kontext der Bioökonomie.

Diese Dissertation generiert darüber hinaus wichtige praktische Implikationen für politische Entscheidungsträger und Industrievertreter. Sie präsentiert wissenschaftlich fundierte Strategien, um die Verbreitung von Innovationen zu beschleunigen, um Innovations-entscheidungen zu beeinflussen und sie zeigt auf, welche Werte und kognitiven Paradigmen im Kontext der Bioökonomie relevant sind. Zum Beispiel signalisiert die Bereitschaft der Konsumenten einen höheren Preis für bio-basierte Plastikverpackungen zu zahlen, dass Unternehmen in diese Art von Verpackungen investieren könnten. Da der Übergang zu einer bio-basierten Wirtschaft jedoch eher von der Veränderung der zugrunde liegenden Glaubenssätze abhängt, bietet diese Arbeit zudem Erkenntnisse über interne Werte und kognitive Paradigmen, die in Schulen und Universitäten gelehrt werden sollten, um einen kulturellen Wandel anzustoßen.

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ALT	Altruism
ASC	Alterative specific constant
AVE	Average variance extracted
BASIC	Basic label information
BASIC_V	Basic control for value activation
BELIEF	Belief activation
BMBF	Federal Ministry for Education and Research
CB-SEM	Covariance-based Structural Equation Modeling
CTRL	Control group
DCE	Discrete choice experiment
NAM	Norm-activation model
NEP	New ecological paradigm
NFC	Need for cognition
NORM	Norm activation
OE	Outcome efficacy
PA	Problem awareness
PI	Purchase intention
PLS-SEM	Partial Least Squares Structural Equation Modeling
PN	Personal norm
RPL-EC	Random parameter logit model with error component
RQ	Research question
SEM	Structural equation modeling
ST	Systems thinking
USA	United States of America
TREAT	Treatment group
VALUE	Value activation
VBN	Value-belief-norm
VIF	Variance inflation factor
WTP	Willingness-to-pay
WVIEW	Ecological worldview activation

1 Introduction

1.1 Research problem and objectives

Why do some people adopt novel behaviors, practices or products while others do not? Why do some people maintain the status quo, even when a new idea has obvious advantages?

In the agricultural and food sector, these questions are of high relevance as novel technologies continuously emerge in order to increase efficiency in agricultural production as well as to provide safer and healthier foods (Godfray et al., 2010; Tian et al., 2016). Currently, the transition from a fossil-based towards a bio-based economy exposes the agri-food sector to a whole set of novel value-added processes, products and services (Boehlje and Bröring, 2011; Bugge et al., 2016). The bio-economy concept combines the use of renewable bio-based materials with biotechnology to tackle the food and energy demand of the growing world population and to deal with depleting fossil resources (Meadows et al., 2004; Godfray et al., 2010; Zilberman et al., 2013; Augustin et al., 2016). Despite these advantages, many economic regions still do not fully take advantage of the bio-economy (Spatial Foresight, SWECO, ÖIR, t33, Nordregio, Berman Group, Infyde, 2017). This type of resistance towards agri-food technologies is not a new phenomenon as it has been commonly observed in the past, e.g. in case of the tractor, pesticides or GM foods (Zilberman et al., 2013; Lusk et al., 2014). However, in order to speed up the bio-economy transition, it is critical to understand the factors that drive the adoption of innovations in this context (Feder and Umali, 1993; Rogers, 2003; Zilberman et al., 2013).

Bio-economy innovations differ from other agri-food innovations as they emerge during the shift from one socio-technical system to another which involves profound cultural changes (Geels, 2004; Geels, 2005). In order to be successful, Meadows (1999) argues that cultural transitions require the change of people's underlying belief systems which motivate their behavior. However, it is not clear which behavioral motivations play a role in the context of the bio-economy transition. Thus, this thesis explores which internal behavioral motivations serve as drivers for the adoption of bio-economy innovations. The following two sections motivate this thesis by establishing the practical relevance of the research problem and by presenting the relevant research gaps that this thesis aims to close.

1.1.1 Practical relevance

The concept of a bio-based economy evolved as an antidote to the current fossil-based economy which entails several unintended consequences for the social and natural system, e.g. climate change (Meadows et al., 2004; Steffen et al., 2015). Into more detail, the bio-economy is characterized by innovation-driven research which aims to replace fossil resources by utilizing biological materials stemming from plants, animals, microorganisms and biological waste streams (Boehlje and Bröring, 2011; Zörb et al., 2018). Specific examples of bio-economy innovations involve the usage of sugar beet pulp to produce bio-based plastics (Eggleston and Lima, 2015), the application of residual tomato leaves as ingredients for food supplements or cosmetics (Junker-Frohn et al., 2019) and the phosphorus recovery from rapeseed and sunflower oil press-cakes (Carraresi et al., 2018). In order to implement this type of innovations, the bio-economy transition involves profound changes in technology, market, infrastructure and cultural meaning (Geels, 2004; Geels, 2005). Thus, it is important that the transition process is stimulated by political bio-economy strategies (Priefer et al., 2017).

World-wide, about 50 countries already adopted policy strategies to support the transition towards a bio-based economic system (Braun, 2018). These policy strategies mainly focus on promoting research and development of new methods to utilize biomass (Priefer et al., 2017). However, a successful transformation needs to focus on more than technological solutions (Geels, 2004). Such a profound shift from a fossil-based to a bio-based economy also requires societal acceptance. In this regard, the involved value chain actors like farmers, processors and consumers need to be willing to accept and to adopt novel farm practices, manufacturing processes and final products (Zilberman et al., 2013; Besi and McCormick, 2015; Urmetzer et al., 2020).

An analysis of the German ´National Research Strategy BioEconomy´ from 2011 and the ´National Policy Strategy on Bioeconomy´ from 2014 reveals that although the importance of public support is recognized (Priefer et al., 2017), there are still two major issues. First, the strategies only focus on participatory dialogues with the general public and the business community, while neglecting the need to reach out to farmers (Federal Ministry of Education and Research, 2011; Federal Ministry of Food and Agriculture, 2014). This approach indicates that policy makers seem to have an instrumental view of farmers, i.e. as the technical providers of biomass (Rossi and Hinrichs, 2011; Schmidt et al., 2012). However, farmers do have distinct perspectives on the bio-economy which need to be taken into account in the transition process (Rossi and Hinrichs, 2011). Moreover, although the diffusion of innovations ultimately depends

on consumer acceptance (Hauser et al., 2006; Arts et al., 2011), current policy strategies ignore questions of how consumers might evaluate bio-based products. Second, in order to achieve support for the bio-economy concept, the German bio-economy strategies only suggest the dissemination of information as the main strategy (Federal Ministry of Education and Research, 2011; Federal Ministry of Food and Agriculture, 2014). This strategy is based on the assumption of human beings acting rationally based on full information (Venkatachalam, 2008). However, insights from psychology and advancements in behavioral economics show that people are motivated by not only information, but also internal factors such as their values and worldviews (Guagnano et al., 1995; Stern et al., 1999) as well as by situational factors such as the framing of choice alternatives (Thaler and Sunstein, 2008; Kahneman, 2011). One of the reasons of why current policy strategies only focus on the dissemination of information might be that the role of internal behavioral motivations for farmers' and consumers' adoption of bio-economy innovation is not understood yet. Thus, the following literature review assesses this assumption into more detail.

1.1.2 Research gap

The adoption of agri-food innovations has been intensively studied over the past decades (Ryan and Gross, 1943; Rogers, 1962; Feder and Umali, 1993; Ghadim, 1999; Bigliardi and Galati, 2013; Frewer et al., 2013; Bossle et al., 2016; Kamrath et al., 2018). The beginnings of innovation adoption research mainly focused on external factors as drivers of the adoption decision such as characteristics of the innovation or specific policy measures (Tarde, 1903; Rogers, 1962; Tornatzky and Klein, 1982). When advancements in psychology shed light into the `black box´ of human decision-making, scientists increasingly discovered the major role of internal mental belief systems in shaping human behavior (e.g. Chomsky, 1959; Bandura, 1969). Since then, innovation adoption scholars also integrated internal motivations such as values and attitudes of the decision-maker into their research (Hassinger, 1959; Frewer et al., 2013; Menozzi et al., 2015; Scalco et al., 2017; Zeweld et al., 2017; Kamrath et al., 2019). Currently, scholars argue that both external and internal factors have substantial impacts on the adoption decision of actors in the agri-food value chain (Ghadim, 1999; Rogers, 2003; Bossle et al., 2016).

However, these insights cannot simply be transferred to the adoption of bio-economy innovations as these innovations distinguish themselves from other agri-food innovations in two particular ways. First, this type of innovations emerges in the context of a transition from

a fossil-based towards a bio-based economy which requires the change of people's underlying belief system such as values, worldviews, beliefs and norms (Meadows, 1999; Geels, 2004). Second, bio-economy innovations have the potential to contribute to the alleviation of environmental problems (Lewandowski et al., 2018). However, the environmental benefits usually occur in the future while the innovations need to be adopted in the present (Baumgärtner and Quaas, 2010). This could represent a barrier as people tend to prefer smaller rewards in the present over larger rewards in the future which is referred to as hyperbolic discounting (Sáez and Requena, 2007; Meyer, 2008). Thus, potential adopters need to be strongly motivated to make short term efforts for long-term environmental benefits (Guagnano et al., 1995; Steg and Vlek, 2009; Faccioli et al., 2016). According to this background, internal behavioral motivations seem to play a major role in the context of bio-economy innovations. However, an overview of the factors that existing literature defines as drivers for the adoption of bio-economy innovations is currently missing.

Thus, an extensive literature review is conducted to elucidate the drivers of value chain actors' decisions to adopt innovations emerging from a transition towards a bio-based economy. To this end, the WebOfScience™ database of Clarivate Analytics is used in August 2019 to provide an overview of existing empirical studies. The following keyword search string was used:

> *TOPIC: ("bioeconomy" OR "bio-economy" OR "biobased*" or "bio-based*") AND TOPIC: ("innov*" OR "techn*" OR "practice" OR "process" OR "product" OR "behavio*") AND TOPIC: ("accepta*" OR "adopt*" OR "percept*" OR "valuation" OR "willingness*" OR "preference") AND TOPIC: ("farmer*" OR "processor*" OR "manufacturer" OR "compan*" OR "retail*" OR "consumer*" OR "public" OR "citizen" OR "stakeholder*" OR "supply chain*")*

The application of the search string resulted in a total of 106 publications. After title and abstract screening for studies focusing on the adoption of bio-economy innovations, 27 studies were identified as relevant for this thesis (see Appendix A).

An in-depth analysis of the publications shows that the number of empirical studies looking at the adoption of bio-economy innovations increased over time. Moreover, most of the studies were conducted in EU countries (n = 24). Only three studies used data from the US, Thailand and South-Africa. Method-wise, the studies employed quantitative research approaches such as surveys and experiments (n = 16) or qualitative approaches such as expert interviews and focus group discussions (n = 11). From a value chain perspective, results show that some studies are dedicated to farmers (n = 4), industry representatives (n = 6) and the general public (n = 5),

while most studies investigate the adoption behavior of consumers (n = 12). Results of these studies are summarized in the following.

Extant studies looking at the adoption behavior of farmers find that these value chain actors are generally skeptical towards bio-economy innovations (Rossi and Hinrichs, 2011). Empirical studies that aim to explain why farmers still adopt these innovations indicate that factors such as agricultural policies, attributes of the innovation and socio-economic characteristics of the farmer are relevant for this decision (Bartolini and Viaggi, 2012; Case et al., 2017; Tur-Cardona et al., 2018). Focusing on industry representatives, exploratory studies identify the following general drivers for the adoption of bio-economy innovations: policy strategies, market prices, R&D activities, firm competencies and societal awareness (Theinsathid et al., 2011; Vandermeulen et al., 2012; Leban et al., 2016; Berg et al., 2018). Further empirical studies provide evidence for the positive impact of policy measures (Lopolito et al., 2015) and labeling of the bio-based content of products in the business-to-business market (Peuckert and Quitzow, 2017). Moreover, the general public seems to lack information which is needed to form a distinct opinion about bio-economy innovations (Mukonza, 2017; Stern et al., 2018; Golowko et al., 2019). Beneficial attitudes towards the bio-economy depend on the degree of engagement with novel technologies, environmental awareness and the general transparency of the life-cycle (Sleenhoff et al., 2015; Lynch et al., 2016). Consumer studies indicate that the final actors in the value chain have both positive and negative associations with the concept of a bio-based economy as well as that they misunderstand the concept of `bio-based´(Sleenhoff et al., 2015; Sijtsema et al., 2016; Stern et al., 2018). However, results of two studies provide evidence that bio-based packaging still seems to increase the preferences for the packaged product (Koutsimanis et al., 2015; Herbes et al., 2018). In terms of drivers for the adoption of bio-economy innovations, these studies mainly investigate socio-demographic characteristics and attributes of the innovation, e.g. whether the product is fully or partially bio-based (Peuckert and Quitzow, 2017; Reinders et al., 2017; Scherer et al., 2017, 2018b; Tur-Cardona et al., 2018). Some studies also assess internal behavioral motivations like attitudes, trust, environmental awareness and social norms as drivers for the innovation adoption (Butkowski et al., 2017; Onwezen et al., 2017; Klein et al., 2019; Russo et al., 2019). However, studies do not integrate theoretical insights on internal drivers of environmental behavior from an environmental psychology perspective (Steg et al., 2005; Price and Leviston, 2014; Klein et al., 2019).

Overall, the literature review reveals two important research gaps. First, existing publications do not consider internal behavioral motivations such as pro-environmental values, beliefs and norms as currently discussed in environmental psychology literature (Stern et al., 1999; Dunlap,

2008; Steg and Vlek, 2009; Lezak and Thibodeau, 2016). Second, current literature does not test specific strategies to encourage value chain actors to adopt bio-economy innovations. For example, existing studies do not consider the context of adoption decisions as a leverage point to influence the behavior of potential adopters (e.g. Thaler and Sunstein, 2008; Schubert, 2017).

1.1.3 Objectives

The research problem can be summarized as follows: the idea of a bio-based economy could make a significant contribution by providing an economic concept that combines economic growth and sustainability (European Commission, 2012; Lewandowski et al., 2018). However, current policy strategies do not sufficiently consider how internal behavioral motivations might encourage or hinder value chain actors to adopt bio-economy innovations. This phenomenon is also reflected in the small number of empirical studies tackling this issue. Although there is a need for research in the context of all relevant value chain actors (Kamrath et al., 2019), this thesis focuses on farmers and consumers as those actors represent the bottlenecks in the transition towards a bio-based economy (Golembiewski et al., 2015). Thus, this thesis aims to achieve two main objectives:

I. To advance the knowledge of how behavioral motivations drive farmers' and consumers' adoption of bio-economy innovations
II. To empirically test strategies to foster the adoption of bio-economy innovations

By achieving these objectives, this thesis renders important practical and scientific contributions. From a practical point of view, this thesis generates ideas for the development of bio-economy strategies that foster the adoption of novel technologies, practices and behaviors. In the scientific context, it enriches the innovation adoption literature by integrating valuable knowledge from environmental psychology and behavioral economics about individual decision-making.

1.2 Theoretical background

Innovation adoption research goes back to Gabriel Tarde, one of the forefathers of social science in Europe, who already investigated the adoption of innovations around 1900 (Tarde, 1903; Rogers, 2003). Tarde (1903) observed that the diffusion of innovations follows specific patterns over time and that opinion leaders and communication networks play an important role in the adoption decision (Rogers, 2003). One of the first and most influential empirical studies which

integrated Tarde's insights was situated in the agricultural domain: an investigation of hybrid seed corn adoption in Iowa (Ryan and Gross, 1943). More studies followed in different disciplines such as education, public health and marketing (e.g. Mort, 1953; Freedman and Takeshita, 1969; Dekimpe et al., 1998). At the same time, insights from psychology inspired innovation diffusion scholars to consider individuals' knowledge, existing attitudes and beliefs as important factors for innovation decisions (Ryan and Gross, 1950; Hassinger, 1959). In 1962, Rogers summarized the findings of current diffusion research into a generalized diffusion model which he published in the first edition of his popular book *Diffusion of Innovations* (Rogers, 1962). Up to the present, this theory is the basis for many empirical studies which aim to explain the motivations behind individuals' innovation adoption.

The first part of the remaining section describes the innovation-decision process developed by Rogers (2003). As the adoption of bio-economy innovations can also be understood as a type of pro-environmental behavior (e.g. Scherer et al., 2018b; Klein et al., 2019), the next subsection presents the current theoretical perspectives that explain environmental behavior. The third subsection gives an overview of recent insights from behavioral economics. This knowledge helps to understand how *nudges* might encourage individuals to adopt innovations (Thaler and Sunstein, 2008).

1.2.1 The innovation-decision process

An innovation is defined by Rogers as `an idea, practice, or object that is perceived as new by an individual or other unit of adoption´ (2003, p.12). In order to explain the process of how individuals adopt these new ideas, practices or objects, Rogers (2003) developed a model of the innovation-decision process. This is the process in which individuals move through several stages towards the decision to adopt or reject an innovation (Rogers, 2003). The whole innovation-decision process model is presented in Figure 1.1.

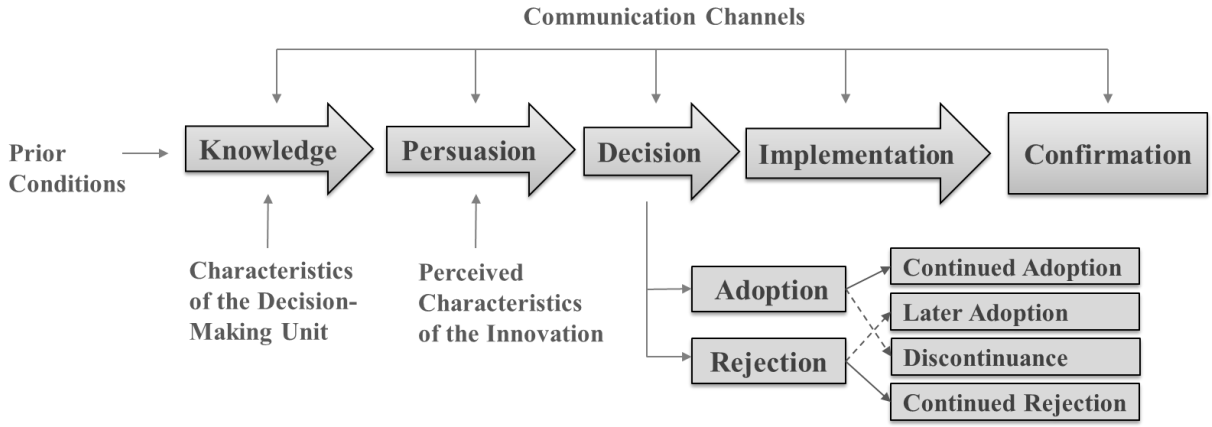

Figure 1.1. The innovation-decision process model.

Source: Own illustration based on Rogers, 2003.

In the first stage, *knowledge*, individuals become aware of the existence of an innovation and gain initial information. Although many individuals are exposed to messages about innovations, only some of them also consciously notice these messages (Rogers, 2003). This phenomenon can be explained by the process of selective perception, which describes that individuals only tend to be interested in information which is consistent with their prior conditions, such as existing values, beliefs, norms or behaviors (Hassinger, 1959; Schwartz and Bilsky, 1987). In addition, more general socioeconomic characteristics, personality variables and communication behavior also influences whether individuals expose themselves to information about innovations (Rogers, 2003). In the second stage, *persuasion*, individuals actively collect more information in order to form an attitude towards the innovation. The formation of the attitude depends on the individual's perception of the various characteristics of the innovation like relative advantage, compatibility, complexity, trialability and observability. Individuals likely form favorable attitudes towards the innovation when opinions of peers confirm the benefits and reduce uncertainties about potential risks associated with the adoption (Rogers, 2003). In the third stage, *decision*, individuals form their decision to either adopt or reject the innovation. In this process, individuals often try out innovations before they fully adopt them. For example, farmers used trial fields for the hybrid corn seeds before they use the seeds on all their corn acreage (Ryan and Gross, 1943). In the next stage, *implementation*, individuals adopt the innovation and change their behavior accordingly. However, it is still possible that they decide to discontinue adopting the innovation if it does not serve their needs anymore. In the final stage, *confirmation*, individuals seek approval for their adoption decision (Rogers, 2003).

In order to accelerate the diffusion of innovations, the main goal is to shorten the length of the innovation-decision process. According to Rogers (2003), this can be achieved through

different communication channels. In the earlier stages of the process, mass media channels are an important resource to spread information about the existence of an innovation among large groups of people. While in the later stages, the communication with personal contacts seems to be more relevant to form strong favorable attitudes towards the innovation (Rogers, 2003)

Transferring these insights to the case of bio-economy innovations which are currently still unknown to many people (Sijtsema et al., 2016), it is assumed that potential adopters are still situated in the knowledge stage. In this case, their perceptions of bio-economy innovations are likely to be (unconsciously) driven by their relatively stable values, general beliefs and norms (Hassinger, 1959; Schwartz and Bilsky, 1987; Rogers, 2003). More specifically, Hassinger (1959) argues that individuals are more likely to be interested in information about an innovation if the innovation has the potential to solve a problem that is relevant to them. Consequently, they `feel the need of the innovation´ (Rogers, 2003, p.171). In the case of the bio-economy, innovations might contribute to the alleviation of environmental threats (Lewandowski et al., 2018). Thus, those individuals who are motivated to engage in pro-environmental behavior to improve the quality of life of future generations might also be more interested in bio-economy innovations (Sleenhoff et al., 2015; Klein et al., 2019). Hence, the next section describes the drivers of pro-environmental behavior which might also be relevant for the adoption of bio-economy innovations.

1.2.2 Drivers of pro-environmental behavior

In the mid-20th century, the general public became increasingly aware of environmental problems and scientists started to uncover the negative impact of human behavior on the natural system (Carson, 1962; Meadows et al., 1972). Since then, scholars intensively studied the behavioral antecedents of pro-environmental behaviors (Schwartz, 1977; Cone and Hayes, 1980; Stern and Gardner, 1981; Guagnano et al., 1995; Stern et al., 1999; Nordlund and Garvill, 2002; Steg et al., 2005; Steg and Vlek, 2009). Pro-environmental behavior is defined by Kollmuss and Agyeman (2010) as *"…behavior that consciously seeks to minimize the negative impact of one's actions on the natural and built world"* (p. 240). This type of behavior often requires individuals to make short-term sacrifices to benefit collective interests (Gifford, 1999; Nordlund and Garvill, 2002). In social science, two main approaches are used to explain the motivation of individuals who are willing to make efforts for the environment (Guagnano et al., 1995; Steg and Vlek, 2009). One group of scholars is studying internal factors such as values, beliefs, attitudes and norms (Schwartz, 1977; Stern et al., 1999; Dunlap, 2008; Steg, 2016), whereas the other group investigates external or contextual factors such as market prices, policy

regulations, infrastructure and characteristics of environmental practices or products (Horbach, 2008; Lopolito et al., 2015; Reinders et al., 2017). As the integration of theories from environmental psychology literature is still missing in the bio-economy context, this thesis focuses on the role of internal behavioral motivations while also integrating the perspective of contextual factors.

In the environmental psychology literature, potential motivations for such pro-environmental behavior are currently studied from different theoretical perspectives: 1) altruistic values (Schwartz, 1977; Rokeach, 1980; Stern and Dietz, 1994), 2) ecological worldview (Stern et al., 1995a; Dunlap et al., 2000) and 3) moral norms (Schwartz, 1977; Davis and Stroink, 2015). *Values* are assumed to evolve during socialization and to be rather stable in adulthood (Rokeach, 1980). These value orientations direct people's attention towards objects they value and, thus, shape their attitudes towards these objects as well as guide their behavior (Rokeach, 1980; Stern and Dietz, 1994; Nordlund and Garvill, 2002). Pro-environmental behavior is mainly driven by altruistic and biospheric values as these value orientations reflect concern for the wellbeing of other human beings, species and the biosphere. As opposed to this, people with an egoistic value orientation, reflecting interest in individual outcomes, are less likely to engage in pro-environmental actions (Stern et al., 1995b; Nordlund and Garvill, 2002; Steg, 2016; Ünal et al., 2018). In contrast to values, *worldviews* reflect general beliefs about reality in a specific domain of life (Stern et al., 1995). The most widely studied worldview dealing with the relationship between humans and the environment is the new ecological paradigm (NEP) (Dunlap et al., 2000). The NEP reflects the beliefs that humans are part of the natural system which is very delicate with limited resources (Stern et al., 1995a; Dunlap et al., 2000). *Moral norms* are defined as feelings of moral obligations to engage in specific behaviors (Schwartz, 1977). The norm-activation model (NAM) uses the construct of personal norms to explain altruistic behavior (Schwartz, 1977; Schwartz and Howard, 1981). Applied to the environmental domain, the NAM postulates that moral obligations to act pro-environmentally are activated when individuals become aware of the consequences of their behavior for the environment and believe that their actions can adverse these consequences (Guagnano et al., 1995; Nordlund and Garvill, 2002; Abrahamse et al., 2007).

The seminal Value-belief-norm (VBN) theory of environmentalism (Stern et al., 1999; Stern, 2000) provides a framework to study these values, worldview and moral norms. The VBN theory postulates a causal chain in which the effect of values on pro-environmental behavior is mediated by individual beliefs and personal norms. As a result, each variable is assumed to not only influence the next variable in the series, but might also potentially affect other variables

down the chain (Stern, 2000). More specifically, relatively stable altruistic and self-interest values are assumed to reinforce an ecological worldview which, in turn, can activate individual awareness of those negative consequences of environmental threats for themselves, others, and the biosphere. Further, if individuals become more aware of consequences involved, this is predicted to activate individuals' perceived ability to reduce these environmental threats, which then strengthens their personal norm to undertake pro-environmental actions (Stern et al., 1999; Stern, 2000).

1.2.3 Strategies to influence behavior

The main environmental policy strategies which economic literature suggested for a very long time were financial incentives (e.g. subsidies) and public information campaigns (Venkatachalam, 2008). One of the reasons behind is that the field of economics was dominated by the paradigm of unbounded rationality (Dietz, 1994; Schubert, 2017). More specifically, the standard neoclassical model assumes that human decision-making is rational and based on the maximization of self-interest (Smith, 1986; Smith and Raphael, 2004).

However, there are two key issues which challenge the viability of the rational choice model for pro-environmental decision making. First, research rooted in environmental psychology and sociology argues that, instead of self-interest, altruistic concerns serve as the main motivation for pro-environmental behavior (Schwartz, 1977; Stern et al., 1995a; Schultz, 1999; Nordlund and Garvill, 2002; Steg and Vlek, 2009). Compared to self-interest, where individuals consider costs and benefits for themselves, altruism drives people to base their decisions on costs and benefits for other people and/or the biosphere (Groot and Steg, 2007).

Second, insights from behavioral and experimental economics indicate that humans do not always behave rationally (Simon, 1979; Kahneman, 2003). Especially under uncertainty and complexity, people were found to rely on intuitive heuristics to reduce their mental effort in the decision-making process (Tversky and Kahneman, 1992; Cialdini and Goldstein, 2004). These findings are important because this is also true for the decision to adopt pro-environmental innovations which involves the consideration of complex interdependencies and high uncertainty about consequences for the environment (Gollier, 2013; Croson and Treich, 2014; Handgraaf et al., 2017).

The assumption that individuals are prone to cognitive biases gave rise to behaviorally informed policy strategies (Schubert, 2017). Prominent examples were introduced by Richard Thaler and Cass Sunstein, commonly known as *nudges* (Thaler and Sunstein, 2003, 2008). Nudges trigger

people to behave in a predictable way by changing the choice architecture, i.e. the context in which decisions are made. The underlying idea is to use behavioral insights about human perception and decision-making, and to create the choice architecture respectively (Thaler and Sunstein, 2008). According to Kahneman (2003), people mostly engage in “fast thinking” which means they act intuitively without spending much cognitive effort or actively deliberating about their choices (“slow thinking”). As fast thinking individuals base their decisions on the information which are accessible in the moment of choice, the most prominent nudging strategy is to make specific information more salient, also called priming (Kahneman, 2003; Thaler and Sunstein, 2008; Schubert, 2017). Examples range from providing labels for pro-environmental product attributes to presenting complex information in a intuitively understandably way (Schubert, 2017). These types of strategies might also be viable to encourage the adoption of bio-economy innovations.

1.3 Research questions

A successful transition towards a bio-based economy requires the involved value chain actors to adopt novel farm practices, manufacturing processes and final products (Zilberman et al., 2013; Besi and McCormick, 2015; Urmetzer et al., 2020). Hence, according to the first objective of this thesis, namely to advance the knowledge of how behavioral motivations drive farmers' and consumers' adoption of bio-economy innovations (see sect. 1.1), this thesis aims to answer four research questions (RQ) which are derived as follows.

The analysis of German bio-economy strategies indicates that policy makers currently do not consider the perspectives of farmers (Rossi and Hinrichs, 2011; Schmidt et al., 2012). In addition, the literature review suggests that the factors shaping farmers interest in bio-economy practices are still not well understood (White and Selfa, 2013). More importantly, empirical studies focusing on farmers do not consider the impact of internal behavioral motivations. Against this background, RQ 1 addresses this gap by examining values, ecological worldview, beliefs and norms as drivers of German farmers' interest in the valorization of horticultural by-products as an example for practices fostering the bio-economy.

RQ 1: Do pro-environmental values, beliefs and norms drive farmers' interest in bio-economy practices?

In addition to these internal motivations, pro-environmental behavior also depends on contextual factors (Guagnano et al., 1995; Steg and Vlek, 2009). As depicted by Horbach (2008), contextual factors especially play an important role for the adoption of eco-innovations. In the case of bio-economy innovations, it is hence necessary to also investigate how farmers perceive the market demand of biomass, bio-economy policies and technology developments. Farmers' perception of these contextual factors might, in turn, depend on their internal belief system (Guagnano et al., 1995). For example, farmers with an ecological worldview (internal) might be more informed about pro-environmental policy measures (external/contextual) (Rogers, 2003). However, empirical insights are still lacking about the interaction between contextual and internal factors in explaining German farmers' adoption of pro-environmental innovations, which is what RQ 2 explores:

RQ 2: How does an ecological worldview relate to farmers' perception of contextual factors?

The second part of achieving the first objective of this thesis is dedicated to the impact of behavioral motivations on the adoption behavior of consumers. Besides pro-environmental values, worldview, beliefs and norms, the concept of systems thinking is currently discussed as a promising internal motivation to explain environmental behavior (Meadows, 2008; Lezak and Thibodeau, 2016). Systems thinking just recently spilled over into social science from interdisciplinary approaches of cybernetics, systems modeling and quantum physics (Bateson, 1972; Senge, 2010). The system lens provides a framework to see a system as a set of interconnected elements with stabilizing and reinforcing chains of causal connections, feedback delays and nonlinear relationships (Meadows, 2008). In the environmental domain, the importance of systems thinking has been increasingly recognized starting from the report for the club of Rome named *The Limits to Growth* (Meadows et al., 1972). The underlying idea is that people tend not to reflect on the negative consequences of their behavior, so that it is difficult for them to grasp how their choices could change things for the better. In this regard, systems thinking (ST) offers one approach to perceive the complex, interconnected nature of reality which allows people to better deal with complex systems such as the ecosystem (Meadows, 2008). Systems thinking is also assumed to be an important cognitive paradigm for a transition towards a bio-based economy (Lewandowski et al., 2018; Urmetzer et al., 2020). For example, people who are aware of the environmental impact of fossil fuels may facilitate a switch to bio-based alternatives (Schwartz, 1977; Urmetzer et al., 2020). However, the current lack of research into the relationship between ST and consumer intentions to buy bio-based products represents a notable shortcoming. As the measure to assess ST is currently only available in English language (Davis and Stroink, 2015), this study draws upon an US sample of consumers. Hence, RQ 3 investigates if systems thinking affects US consumer intention to purchase bio-based products as an example of bio-economy innovations.

RQ 3: Does systems thinking affect consumer intention to purchase bio-based products?

The psychological mechanism of how systems thinking affects pro-environmental decision-making is not finally understood yet (Lezak and Thibodeau, 2016; Davis et al., 2017; Ballew et al., 2019). Systems thinking might offer a substitute for other factors known from environmental psychology literature, such as values and norms, or its importance for pro-environmental purchasing decisions might be independent (Davis and Stroink, 2015; Ballew et al., 2019; Klein et al., 2019). Thus, RQ 4 aims to discover the relationship between systems thinking and values, worldview, beliefs and norms into more detail.

RQ 4: How does systems thinking relate to consumers' values, ecological worldview, beliefs and norms?

The second objective of this thesis is to investigate strategies that foster the adoption of bio-economy innovations. To achieve this objective, this thesis aims to answer two research questions.

Current bio-economy strategies do not integrate insights from behavioral economics about the decision-making context as an important leverage point to foster the bio-economy transition (Thaler and Sunstein, 2008; Kahneman, 2011). For example, recent studies suggest that pro-environmental behavior can be triggered by green nudges which aim to design the choice context in a way that it a peoples' pro-environmental values, beliefs and social norms (Nolan et al., 2008; Steg and Groot, 2010; Hahnel et al., 2014). However, it is not known whether green nudges also encourage consumers to adopt bio-economy innovations. Thus, RQ 5 assesses the effectiveness of green nudges in increasing German consumer willingness to pay for bio-based plastic packaging as an example of a bio-economy innovation.

RQ 5: Which green nudges increase consumer willingness to pay for bio-based plastic packaging?

The effectiveness of green nudges might differ between people who base their decisions on rational arguments and people who base them on their intuition or emotions (Smith and Levin, 1996; Carnevale et al., 2011). However, current studies found contradictory results regarding the interaction of people's cognitive style and choice contexts (Mandel and Kapler, 2018). Hence, RQ 6 explores how consumers' cognitive styles impact the effectiveness of green nudges that trigger pro-environmental values, worldview, beliefs and norms.

RQ 6: How do individual differences in consumers' cognitive styles impact the effectiveness of green nudges?

1.4 Research designs and analytical approaches

In this thesis, three empirical studies were conducted to answer the research questions as presented before (see 1.3). All studies are based on *primary data* from farmers or consumers collected via telephone interviews or online surveys. The remaining section gives an overview of the employed research designs and analytical approaches which are also summarized in Table 1.1.

In all three studies, the measurements of the *dependent variables* rely on the *stated preferences* approach, i.e. the participants had to reply to hypothetical situations such as the decision to purchase tomatoes with either bio-based or fossil-based plastic packaging. In contrast, *revealed preferences* are based on real choices of individuals, e.g. the products an individual actually bought in the grocery store. The advantage of this approach is that the data reflects real choices. However, the stated preferences approach allows to estimate if people adopt innovative procedures or products that do not exist yet (Louviere et al., 2000).

To explore the relationship between the dependent and the independent variables used to investigate the underlying research questions, this thesis employs both *correlational and experimental study designs*.

Correlational research designs aim to detect the systematic associations between the measured variables. However, correlational studies do not allow to draw conclusions about the causal relationships between these variables. In contrast, experimental study designs manipulate situations or experiences of individuals and observe the effect of these manipulations on the outcome variable (Stangor, 2015).

In this thesis, the correlational design is used in the first study to assess the relationships between farmers' internal behavioral motivations, perceived contextual factors and their interest in the utilization of agricultural by-products (chapter 2). The second study employs a mixture of correlational and experimental design to test the effect of systems thinking on consumer intention to purchase bio-based products (chapter 4). This study utilizes a *between-subject-design* that randomly assigns participants either to the control group or the behavioral treatment group which aims to activate systems thinking. The randomized assignment of participants allows to attribute the differences in consumer intention to the behavioral treatment (Stangor, 2015). The third study uses an experimental research design and employs a *discrete choice experiment* (DCE) to assess the effects of bio-based packaging on consumer preferences for cherry tomatoes (chapter 5). The DCE is a method to observe decision-makers choices

between discrete alternatives (Train, 2009; Hensher et al., 2015). In this study, participants are provided with several choice situations with two alternatives of cherry tomatoes with different attributes (e.g. the type of packaging) and a `no-purchase´ alternative. In addition, a between-subject-design is employed to assess the effects of different green nudges on consumer preferences. Thus, participants are randomly assigned to different treatment groups before they pass through the choice experiment.

Mediation analysis is utilized in the second study to explore the mechanism that leads systems thinkers to purchase bio-based products (chapter 3). Mediation generally assumes that a predictor variable (X) affects a second variable (M) that, in turn, affects the outcome variable (Y), so that M mediates the relationship between X and Y. In this case, an ecological worldview, beliefs and norms are explored as mediators for the relationship between systems thinking and consumer intention to purchase bio-based products. To estimate the direct effects between X, M and Y and the indirect effect of X through M on Y, this thesis uses a regression-based approach (Hayes, 2018).

Discrete choice modeling is applied in the third study to elicit consumer preferences for bio-based packaging based on data from the discrete choice experiment (chapter 4). As applied choice models are consistent with the random utility theory (McFadden, 1974), the utility that individual *n* derives from alternative *j* at choice occasion *t* can be expressed as follows:

$$U_{njt} = V_{njt} + \varepsilon_{njt} \quad (1)$$

where V_{njt} denotes the observed component of utility and ε_{njt} represents the stochastic and unobserved component. Depending on the underlying assumptions about individual preferences, different econometric models can be specified. For example, the random parameter logit (RPL) model assumes preferences for product attributes to be heterogeneous as well as correlated with each other (Hensher et al., 2015). Thus, the RPL model is appropriate in the context of packaged cherry tomatoes.

Table 1.1. Details of the empirical studies within this thesis.

Study	Research questions	Dependent variable	Independent variables	Data	Research Design	Data Analysis	Publication status
I	**RQ 1:** Do pro-environmental values, beliefs and norms drive farmers' interest in bio-economy practices? **RQ 2:** How does an ecological worldview relate to farmers' perception of contextual factors?	Farmers' interest in the utilization of agricultural by-products	Values, ecological worldview, beliefs, norms, perceived contextual factors	German Farmers (N = 96)	Quantitative telephone surveys	Structural equation modeling	Published 2019 in *Journal of Environmental Management* (JIF: 4.865, VHB-JQ3: B/C)
II	**RQ 3:** Does systems thinking affect consumer intention to purchase bio-based products? **RQ 4:** How does systems thinking relate to consumers' values, ecological worldview, beliefs and norms?	Consumer intention to buy bio-based products	Systems thinking, values, ecological worldview, beliefs, norms	US Consumers (N = 446)	Online-survey with a between-subject design	Mediation Analysis	*Under review*
III	**RQ 5:** Which green nudges increase consumer willingness to pay for bio-based plastic packaging? **RQ 6:** How do individual differences in consumers' cognitive styles impact the effectiveness of green nudges?	Consumer preferences for tomatoes with bio-based plastic packaging	Product attributes, communication strategies, Need for cognition	German Consumers (N = 1019)	Online discrete choice experiment with a between-subject design	Random Parameter Logit Model	Published 2020 in *Ecological Economics* (JIF: 4.281, VHB-JQ3: B)

Source: Own illustration.

1.5 Structure of the thesis

This thesis is structured in five chapters as follows: Chapter 1 motivates this thesis by demonstrating both the practical relevance as well as the existing research gap concerning behavioral motivations as drivers for the adoption bio-economy innovations. It further explains the relevant theoretical background and derives the research questions. Chapters 2-4 present the empirical studies that were conducted within this thesis. Figure 1.2 depicts how these chapters are associated with the objectives and research questions presented in the previous sections.

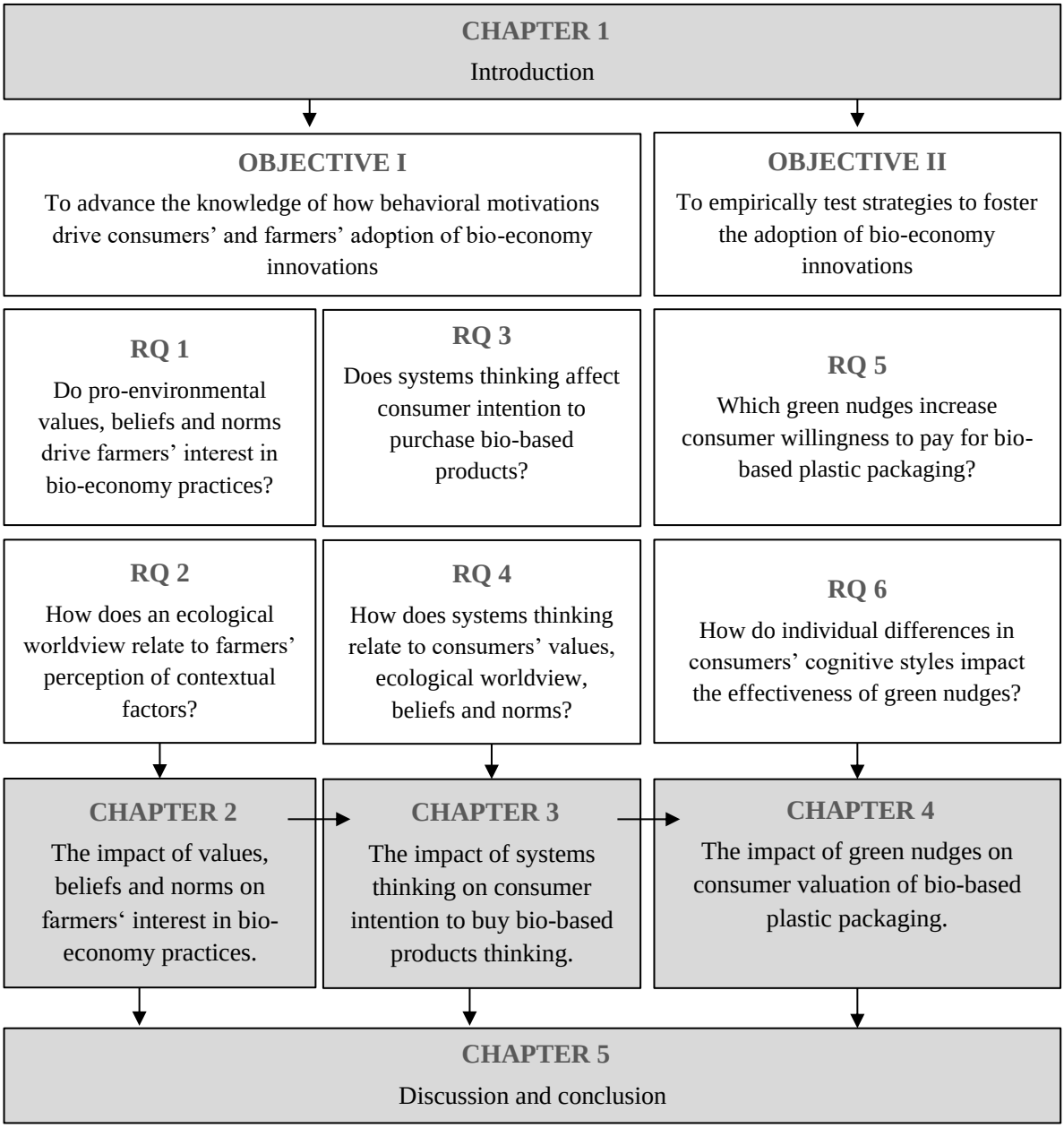

Figure 1.2. Overview of the structure of the thesis.

Source: Own illustration.

Chapter 2 assesses the effect of behavioral motivations on farmers' interest in the adoption of bio-economy practices, using the case of the utilization of horticultural by-products as an example. A survey with German fruit and vegetable farmers has been carried out and data have been analyzed with a Structural Equation Model. Findings suggest that pro-environmental values, beliefs and norms are relevant to predict farmers' interest in bio-economy practices. Results further indicate that an internal ecological worldview is potentially relevant for farmers' perception of contextual conditions aimed to foster the bio-economy.

Chapter 3 explores systems thinking as a behavioral motivation for consumer adoption of bio-based products, using the intention to buy bio-based products as a proxy. The study uses an online survey with a between-subject design to situate systems thinking in relation to altruistic values, an ecological worldview, beliefs and norms as well as intention to buy bio-based products. This study provides empirical evidence that a behavioral task in which consumers reflect about the consequences of their own consumption behavior is successful in activating a systems thinking perspective which, in turn, affects their intention to purchase bio-based products. Moreover, that relationship between systems thinking and purchase intention seems to be mediated by consumers' problem awareness, outcome efficacy and personal norms.

Chapter 4 investigates the effectiveness of green nudges to increase consumer willingness to pay for bio-based products, using the case of bio-based plastic packaging as an example. The study uses a discrete choice experiment with a between-subject-design to activate consumer pro-environmental values, worldviews, beliefs or norms by providing them with nature pictures, reflection questions, information and social proof, respectively. Results indicate that the strongest effects are generated when the nudging strategy matches the characteristic of consumers' cognitive style.

Chapter 5 summarizes and discusses the insights of this thesis as well as presents the theoretical, methodological and empirical contributions. It also derives practical implications for managers and policy-makers in the bio-economy domain and, finally, concludes with limitations and potential directions for further research about behavioral motivations as drivers for the adoption of bio-economy innovations.

2 The impact of values, beliefs and norms on farmers' interest in bio-economy practices

"Individuals tend to expose themselves to ideas that are in accordance with their interests, needs and existing attitudes"

Everett M. Rogers (1962)

Chapter 2 answers the following research questions:

RQ 1: Do pro-environmental values, beliefs and norms drive farmers' interest in bio-economy practices?

RQ 2: How does an ecological worldview relate to farmers' perception of contextual factors?

This chapter is based on the following publication:

Wensing, J., Carraresi, L. and Bröring, S. (2019). Do pro-environmental values, beliefs and norms drive farmers' interest in novel practices fostering the Bioeconomy? *Journal of Environmental Management*, 232: 858-867.

2.1 Introduction

Horticultural by-products (i.e. vegetable leaves), which tend to be currently underutilized, have the potential to be valorized as feedstock for a wide range of bio-based products (Godoy-Durán et al., 2017). Thus, the utilization of by-products increases the availability of biomass while avoiding a conflict with food production (Boehlje and Bröring, 2011). Moreover, residues of fruit and vegetable production are rich in health-promoting active components, which can be extracted and used as ingredients in several products (e.g. cosmetics) (Pleissner et al., 2016; Wensing and Bröring, 2017). Even after prioritizing these uses, residual biomass can be further utilized for less quality-intensive purposes such as energy production (Allen et al., 2013).

When adopted by farmers on a large scale, the valorization of by-products is expected to contribute to the alleviation of negative consequences for the ecosystem, such as the broad dependency on fossil resources, mitigation of climate change impacts, and the shift away from the linear "take-make-dispose" economy (Golembiewski et al., 2015; Pleissner et al., 2016). Thus, this novel practice can also be understood as a type of pro-environmental behavior.

However, from the perspective of farmers, the valorization of horticultural by-products requires a new level of engagement, given that by-products have to be collected, dried and then delivered to bio-refineries or industrial partners for further processing (Keegan et al., 2013). These potential changes in organizational procedures lead to high uncertainty among farmers, so that they still have to define their attitudes towards the practice to valorize by-products (Rossi and Hinrichs, 2011). To form an attitude, which is seen as a precondition to adopt or reject novel technologies or practices, individuals need to collect information about potential costs and benefits of the innovation (Rogers, 2003). The motivation to gather more information about novel sustainable practices is in turn driven by rather stable pro-environmental values, beliefs and normative concerns (Steg and Vlek, 2009). Therefore, this study draws upon the value-beliefs-norm (VBN) theory of environmentalism (Stern et al., 1999) to predict farmers' motivation to collect information about the valorization of by-products. Moreover, farmers' motivation may also be facilitated or constrained by contextual factors such as the market demand for biomass, agricultural subsidies or infrastructure (Bloomberg New Energy Finance, 2012; Bröring et al., 2017). Therefore, it is pivotal to examine both internal and contextual conditions as well as the interaction between them in order to understand farmers' interest in valorizing by-products.

The objectives of this paper are thus threefold. First, it applies the VBN theory to assess the relationship of pro-environmental values, beliefs and norms vis-à-vis fruit and vegetable

farmers' motivation to learn more about valorizing by-products. Second, it examines farmers' perceptions of the pro-environmental effectiveness of the process and, moreover, their understanding of the contextual factors that are most relevant to the transition towards a Bioeconomy as additional contextual antecedents of farmers' interest to valorize by-products. Third, the paper explores the nature of the interaction between ecological worldviews and farmers' perceptions of contextual factors. Thereby, this study contributes towards the more comprehensive understanding of factors shaping farmers' interest to valorize by-products as a practice aimed to foster the Bioeconomy.

2.2 Literature review

2.2.1 State of research

Recent studies have integrated a more social science-informed perspective in order to explain farmers' decisions to adopt pro-environmental practices. For example, studies have shown that farmers' internal attitudes are a crucial determinant of the adoption of practices such as water conservation (Yazdanpanah et al., 2014), maintenance of ecological focus areas (Menozzi et al., 2015), manure separation technology (Gebrezgabher et al., 2015), and use of minimum tillage and row planting (Zeweld et al., 2017). This paper utilizes the framework of the VBN theory which is shown to be relevant for domains ranging from the acceptability of energy policies (Steg et al., 2005) and recycling behavior (Aguilar et al., 2013) to willingness to pay for park conservation (López-Mosquera and Sánchez, 2012). Support for its application to the agricultural domain has also been found for farmers' intention to adopt practices related to both natural resource management (Seymour et al., 2010) and land management (Price and Leviston, 2014).

However, farmers' pro-environmental behavior is also influenced by contextual factors such as policy incentives and farm- and management-related characteristics (Knowler and Bradshaw, 2007; Bartkowski and Bartke, 2018). According to Horbach (2008), contextual factors facilitating or hampering the diffusion of environmental innovations can be organized in three main groups: i) market pull ii) regulatory push and iii) technology push. Regarding the first of these, the diffusion of environmental innovations can be pulled by the market, e.g. owing to expectations that the innovation is likely to be profitable. For instance, the increased environmental awareness among consumers leads to a growing demand of sustainable products and services (Pavitt, 1984). In the Bioeconomy context, the so far limited consumer understanding of the benefits of bio-based products may reduce the market demand of biomass

and, in turn, the profitability of valorizing by-products (Allen et al., 2013). Second, the broad regulatory climate has been shown across several sectors to influence the diffusion of environmental innovations (Horbach et al., 2012). Farmers in the European Union currently do not receive any financial incentives for the collection and/or transport of their by-products. Instead, extant policy initiatives have mainly focused on uses for bio-energy, and with limited attention to potential applications for bio-chemicals and bio-materials (Bloomberg New Energy Finance, 2012). Finally, technology developments which lead to more affordable innovations with improved functionality or novel technological capabilities are likely to facilitate a more rapid implementation (Horbach, 2008). In the case of horticultural by-products, research uncovering the potential application fields for bio-active components is still ongoing (Pleissner et al., 2016). Moreover, existing infrastructure and logistical processes for the transport and storage of biomass are often either unavailable or inefficient (Bröring et al., 2017).

These contextual barriers and the lack pro-environmental values, beliefs and norms might reduce farmers' willingness to engage in the valorization of by-products (Rossi and Hinrichs, 2011). However, the impact of these factors is still not empirically tested which is the aim of this paper.

2.2.2 Conceptual model and hypotheses

The final dependent variable in this study captures farmers' interest to gather more information about valorizing by-products. In specific, this is seen as a precondition for the formation of an attitude towards this innovation and, in turn, ultimately making a decision about whether or not to adopt this practice (Rogers, 2003; Wolske et al., 2017). The conceptual model is presented in Figure 2.1.

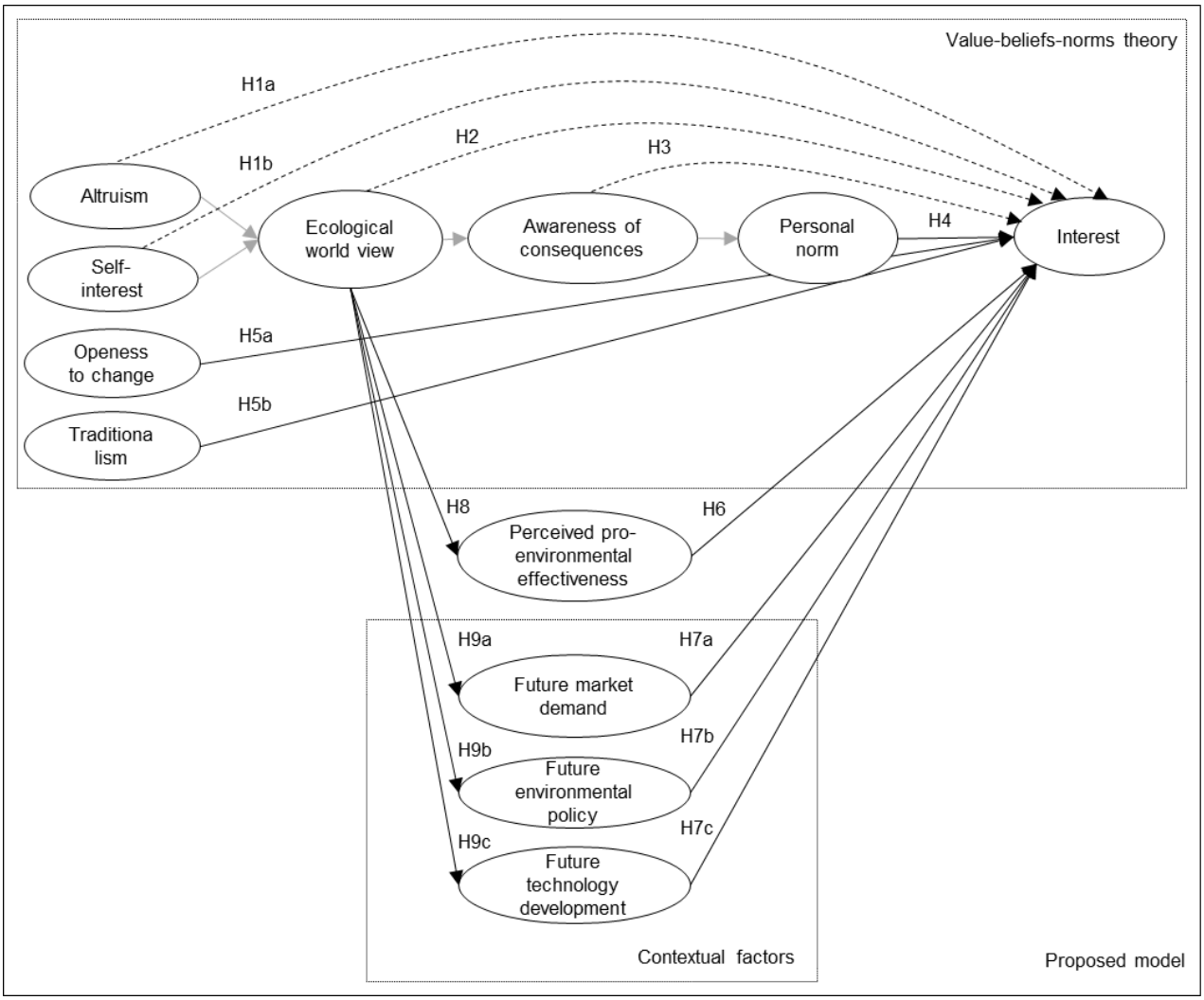

Figure 2.1. Conceptual model and hypotheses.

Note: Dashed arrows indicate indirect effects.

Based on Stern (2000), it is hypothesized that altruistic values and self-interest values affect – positively and negatively, respectively - the ecological worldview of farmers which, in turn, is positively related to the awareness of consequences vis-a-vis climate change, the current dependency on fossil resources, and the reliance on a linear "take-make-dispose" economy (H1a, H1b, H2). Awareness of consequences of these environmental threats is specifically understood to activate the personal norm to act (H3) and finally farmers' interest to collect information about valorizing by-products (H4).

Empirical studies in the context of central Europe have shown that farmers, compared to the general public, are more likely to be skeptical towards innovations and not so interested in novelty for its own sake (Baur et al., 2016). Therefore, value profiles of farmers might be the reason for the slow uptake of pro-environmental agricultural innovations (Baur et al., 2016),

e.g. because they are more "traditional" by nature. For example, in the case of Dutch farmers, their innovativeness has been found to positively affect their decision to build a sustainable stable (Kemp et al., 2014). Due to the novelty of attempts to valorize by-products, this study also aims to capture innovativeness through the variables of openness-to-change values and traditionalism (Schwartz and Bilsky, 1987; Stern et al., 1998); which, respectively, can be hypothesized to be positively and negatively related to farmers' interest in valorizing by-products (H5a, H5b). Furthermore, assessing the innovativeness of farmers also serves to identify lead users who adopt innovations earlier than their followers (Rogers, 2003).

If individuals are aware of the negative consequences of their behavior, they are more likely to perceive a moral obligation to change their behavior (Stern et al., 1999; Stern, 2000). However, it is important that individuals also believe that they are able to alleviate these negative consequences by their actions (Stern et al., 1995b). In this regard, Rajendran et al. (2016) found that the more farmers perceive sustainable agricultural practices to have pro-environmental benefits (e.g. via reduced impact of chemical pesticides), the more willing they will be to adopt them. Therefore, farmers who expect the valorization of by-products to have positive effects on the environment are assumed to be more interested to learn more about these practices (H6).

Moreover, several empirical studies indicate that the perceived profitability of pro-environmental agricultural practices (e.g. soil conservation) and the existence of policy measures like subsidies positively influence farmers' adoption decisions (Knowler and Bradshaw, 2007; Baumgart-Getz et al., 2012; Rajendran et al., 2016). Based on the main contextual factors influencing the diffusion of environmental innovations identified by Horbach (2008), those farmers who believe that the market demand, environmental policy measures and technology developments will evolve in favor of the Bioeconomy, are assumed to be interested in collecting information about valorizing by-products (H7a, H7b, H7c).

These external conditions such as the future market demand for biomass or pro-environmental effectiveness of valorizing by-products are likely to be perceived and evaluated differently by farmers owing to the influence of individual values and beliefs (Guagnano et al., 1995). This process can be explained using the concept of selective perception, which describes the potential for bias in how information is likely to be subjectively perceived and differently evaluated based on one's existing value system (Hassinger, 1959; Rogers, 2003). This has not yet been applied in relation to farmer decision-making however. Nonetheless, the stability and generality of values and beliefs across a range of domains means that they can also serve as the foundation for attitude formation towards unknown agricultural practices and future

developments in the Bioeconomy (see (Stern et al., 1995b). Thus, an ecological worldview is expected to affect farmers' perceptions of the pro-environmental effectiveness of valorizing by-products and of future external developments favoring the Bioeconomy (H8, H9a, H9b, H9c).

2.3 Methods

A questionnaire survey was designed for fruit and vegetable farmers across Germany to identify those factors driving their interest to learn more about the valorization of by-products. Data has been collected in August 2017 via telephone interviews, in cooperation with Kleffmann Group, a provider of agricultural market research services. Fruit and vegetable farmers throughout Germany were randomly selected from an internal database and received incentives for participation.

2.3.1 Measures

Before creating the survey, the hypotheses were pre-tested on the basis of qualitative data from five interviews with fruit and vegetable farmers. Inspired by Wolske et al. (2017), the measure used to assess farmer interest consists of five items capturing the motivation of learning more about advantages and disadvantages of the practice from other farmers or companies and the intention to talk to companies that might be willing to collect their horticultural by-products.

Concerning the independent variables extracted from the VBN-theory, validated measures from the literature were adopted and adjusted (Stern et al., 1999; Diekmann and Preisendörfer, 2003; Wolske et al., 2017). All items are measured on a Likert scale from 1 to 7, where 1 = do not agree at all, and 7 = absolutely agree.

In order to measure farmer perception of the pro-environmental effectiveness of valorizing by-products, three items were developed to capture the expected impact on climate change, the dependency on fossil resources, and the circular economy. For variables representing farmer beliefs about external influences, items were created by drawing on the three main contextual factors influencing the diffusion of environmental innovations identified by Horbach (2008). For example, the variable future market demand included items about future demand of biomass residuals as well as pressure from food retailers and consumers. All these measures are presented in Appendix B.

2.3.2 Evaluation of the measurement model

In order to test the relationships between the latent constructs, Partial Least Squares Structural Equation Modelling was applied (PLS-SEM) and the software Smart-PLS 3.0 was used for the analysis. The constructs in this study are based on a reflective measurement model as all indicators are assumed to be caused by the construct and, therefore, are interchangeable and correlated with each other (Hair et al., 2014). The complete structural model is illustrated in Figure 2.2.

To test the fit of the reflective measurement model to the empirical data, reliability and validity of the constructs were evaluated using those measures suggested by Hair et al. (2014) (Appendix C). The majority of the indicators used for the final structural model had outer loadings with an acceptable level of (at least) 0.7. Moreover, while a few indicators had loadings between 0.5 and 0.7, they were retained in the model due to their contributions to content validity (Hair et al., 2014). All other indicators with lower levels of outer loadings and indicator reliability were deleted.

Composite reliability was also used to test for internal consistency (Hair et al., 2014; Weiber and Mühlhaus, 2014), and with acceptable values, i.e. above 0.7, found for all variables. Further, to assess convergent validity, the average variance extracted (AVE) was calculated for each construct. The values of AVE for all constructs are above the level of 0.5, while the value for future market demand is close to 0.5. This indicates that more than 50% of the variance of indicators can be explained by the construct (Hair et al., 2014). Making use of the Fornell-Larcker Criterion to examine divergent validity (Fornell and Larcker, 1981), it was tested whether the square root of each construct's AVE is greater than its correlations with other latent variables. Results indicate that all constructs meet this criterion, thus suggesting that they are sufficiently distinct from each other in the path model (Appendix D).

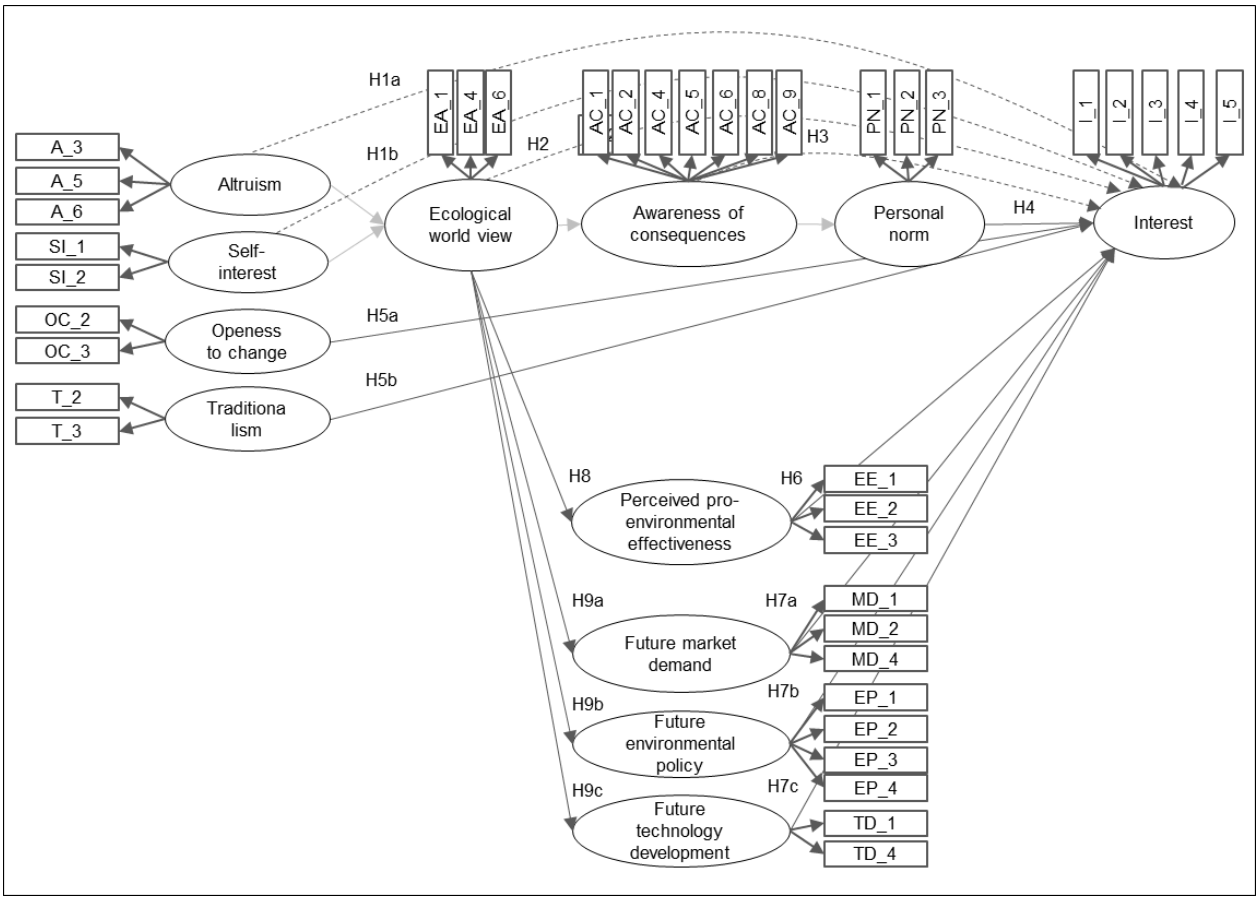

Figure 2.2. Structural model and measurement model.

2.3.3 Estimation of the structural model

Before assessing the significance of the relationships between the latent constructs and the overall predictive accuracy of the structural model, the variance inflation factor (VIF) was calculated for the independent variables to assess potential collinearity. According to Hair et al. (2014), collinearity is revealed through VIF values below 0.2 and above 5. Hence, the data are not affected by collinearity, given that the VIF values in the model range from 1.36 (future environmental policy) to 2.83 (awareness of consequences). Finally, a bootstrap resampling procedure was applied with 5,000 sample sets to calculate confidence intervals for parameter estimates.

2.3.4 Sample characteristics

In total, from 285 contacted farmers who fulfilled the requirements of this study; 101 were ultimately willing to participate (response rate of 35 %). Due to missing values exceeding 10% of responses, five participants were removed from the dataset (Hair et al., 2014), leading to a final sample of 96 respondents.

The average age of farmers in the sample is 57 years (SD = 15.25, range = 19-87), and the majority of the respondents are male (n = 90). Mean farm size is 67.89 acres (range = 1.75-630), with the median annual turnover between 250,000€ - 500,000€. Descriptive results show that half of the farmers in the sample are rather motivated to learn more about valorizing by-products (Mdn = 4.80, M = 4.45, SD = 1.73).

2.4 Results

Before testing the various hypotheses, it was first examined whether or not the data support the assumption that the VBN variables are organized in a causal chain. As stated in the theory, altruism positively ($\beta = 0.46$, $p \leq 0.00$) and self-interest negatively ($\beta = -0.20$, $p \leq 0.10$) affect the strength of ecological worldviews. Furthermore, farmers' ecological worldview then has a positively influence on their awareness of consequences of negative threats ($\beta = 0.56$, $p \leq 0.00$), which in turn positively affects the strength of personal norms to act in order to protect the environment ($\beta = 0.42$, $p \leq 0.00$). According to these results, each variable indeed determines the next variable in the succession, thus demonstrating that the causal chain of the VBN model is applicable in the context of this study. The results for the direct and indirect effects of the exogenous variables on the endogenous variable interest are presented in Table 2.1.

Table 2.1. Results of the structural equation model.

Hypotheses	Constructs	Model 1	Model 2	Model 3
H1a	Altruism [a]	0.19*	0.16*	0.18*
H1b	Self-Interest [a]	-0.08	-0.08	0.08
H2	Ecological worldview [a]	0.06	0.10	0.25*
H3	Awareness of consequences [a]	0.19**	0.15**	0.16**
H4	Personal norm	0.46***	0.35***	0.38**
H5a	Openness-to-change	0.33***	0.30**	0.33***
H5b	Traditionalism	0.20	0.20	0.14
H6	Perceived effectiveness		0.33***	0.28**
H7a	Market demand			0.37**
H7b	Environmental policy			0.08
H7c	Technological development			-0.20*
	R2	0.23	0.31	0.41
	f2		0.11	0.16

Note: * $p \leq 0.1$; ** $p \leq 0.05$; *** $p \leq 0.01$; f2 = (R2 included – R2 excluded) / (1 – R2 included) [a] modelled to have an indirect effect on farmer interest

Model 1 includes the variables from the VBN-theory, to which perceived pro-environmental effectiveness of valorizing by-products was added to form Model 2, followed by the beliefs

about external factors to form Model 3. To assess whether the added exogenous constructs in Models 2 and 3 have a substantial impact on the ability to explain the endogenous variable, the effect size was calculated. Following Cohen (1988), values of $f2 \geq 0.02$, $f2 \geq 0.15$, and $f2 \geq 0.35$ represent small, medium and large effects, respectively.

Model 1 explained 23% of the variance in farmers' interest to learn more about valorizing by-products. Results show that altruism ($\beta = 0.19$) and awareness of consequences ($\beta = 0.19$) both indirectly influence the endogenous construct, whereas personal norms ($\beta = 0.46$) have a more direct effect on interest. The variables self-interest and ecological worldview do not have a significant (indirect) impact. In accordance with extant literature on innovation management (Jansson, 2011; Pino et al., 2017; Wolske et al., 2017), Openness-to-change ($\beta = 0.33$) has a positive impact on farmers' interest to learn more about valorizing by-products. However, traditionalism has no significant impact. Generally speaking, the results of this study congruent with the theoretical prediction of Stern et al. (1999) that relatively stable values and general beliefs have an indirect impact on farmers' decision making (Price and Leviston, 2014).

Regarding Model 2, the inclusion of the additional variable results in an explained variance of 31%, thus adding a further 8% compared to Model 1. In specific, perceived pro-environmental effectiveness has a positive and significant impact on farmers' interest to learn more about valorizing by-products ($\beta = 0.33$). Overall, the additional variable is found to have a medium effect-size on the endogenous variable ($f2 = 0.11$). This provides support for the presumption of Stern et al. (1999) that it is necessary for individuals to not only be aware of negative consequences for the environment but to also believe in their ability to alleviate these threats through their actions.

Finally, Model 3 explains 41% of the variance in farmers' interest to learn more about valorizing by-products, with addition of the three external factors offering a further 10% of explained variance. The f2 value (0.16) moreover indicates that the inclusion of these variables had a medium effect on explaining the overall variance in farmers' interest. Compared to Model 2, ecological worldview has a significant (indirect) effect on farmer interest ($\beta = 0.25$). Looking at the contextual factors, future market demand exercises a positive and significant effect on interest ($\beta = 0.37$), indicating that those farmers who believe that valorizing by-products will be profitable in the future are generally more motivated to collect the information necessary to make a decision. This finding is broadly consistent with the agricultural economics literature, wherein it is indicated that the perceived profitability of an innovation is a driver for adoption behavior (Cary and Wilkinson, 1997; Morgan et al., 2015). In contrast, the analysis reveals a

(moderately) negative relationship between perceived future technology development (β = -0.20) and farmers' interest. One explanation could be that these farmers are more likely to think that developments of science and technology are able to offer broad solutions for environmental problems (Huesemann, 2001), and thus pro-environmental practices are not needed. Moreover, there is no evidence of a relationship between farmer perceptions of future environmental policy and their interest in valorizing by-products, which conflicts with previous studies (Baumgart-Getz et al., 2012; Rajendran et al., 2016). Indeed, all in all, the only contextual factor able to predict farmer interest in valorizing by-products is future market demand, that is, how strong the market for such products is likely to be in the future. In comparison to the factors of the VBN framework, the overall explanatory power of these contextual factors is notably lower. Therefore, while it is crucial to continue exploring the contextual factors on decision-making, agri-environmental research is needed more urgently into the relevance of altruistic values and pro-environmental beliefs for understanding farmer behavior.

Furthermore, to assess the interaction between internal and contextual factors, the path coefficients were calculated between ecological worldviews and farmers' beliefs about external factors. This analysis illustrates that farmer perceptions of the pro-environmental effectiveness of valorizing by-products is both positively and significantly related to the strength of their ecological worldviews ($\beta = 0.24$, $p = 0.03$). Furthermore, beliefs about future market demand ($\beta = 0.28$, $p = 0.10$) as well as future environmental policy ($\beta = 0.24$, $p = 0.03$) are also both positively related to their ecological worldviews. These positive relationships show that an ecological worldview of farmers has a strong indirect effect on their overall interest in investing time to research these practices. By contrast, the path between ecological worldview and future technology development is found to not be significant, perhaps due to the fact that technology developments related to valorizing by-products are not generally driven by environmental concern but rather efficiency.

However, despite positive associations between an ecological worldview and contextual factors (e.g. MD and EP) the direction of causality still remains to be investigated. In this vein, a growing body of research in the behavioral sciences suggests that internal factors such as emotions and interpersonal knowledge shape how people and objects in the external world are perceived and evaluated (Baum and Gross, 2017; Otten et al., 2017). As such, internal factors like pro-environmental beliefs can indeed be expected to act in concert with and strengthen the perception and evaluation of the broader contextual developments.

2.5 Discussion

The first objective of this study was to examine the influences of values, beliefs and norms on levels of farmer interest in practices aimed to foster the Bioeconomy. The results of this study provide evidence that the VBN theory is indeed a useful framework to understand the interest of German farmers in learning more about valorizing by-products. In fact, the amount of the variance in farmers' interest explained by the VBN model is similar to studies that have previously applied the model to consumer research (Steg et al., 2005; Wolske et al., 2017). Regarding the second objective, the results show that farmer perceptions of both the pro-environmental effectiveness of valorizing by-products and of contextual factors additionally explain their interest in learning more about these innovative practices. By measuring farmers' interest, operationalized as a behavioral intention to gather more information, the open gap towards the next step in the decision process in which individuals already have a predefined attitude and come to an adoption decision was closed (Kaplan, 1999; Rogers, 2003). Indeed, empirical studies found that after collecting information about novel practices farmers are also more likely to adopt these practices (McNamara et al., 1991; Llewellyn et al., 2007; D'Emden et al., 2008). However, the main contribution of this study is that farmer perceptions of contextual factors are inextricably connected to the strength of their ecological worldview, thus indicating a relationship between external circumstances and internal belief systems (Guagnano et al., 1995).

2.5.1 Limitations and further research

The motivation to learn more about valorizing by-products is a necessary but not sufficient condition for farmers to adopt related agronomic practices. Therefore, future studies need to examine factors that might be more relevant for the later stages of adoption decisions, in which farmers finally make an adoption decision. At the early stages, when the innovations are relatively unknown, general values can offer broad guidance, but as soon as farmers develop specific beliefs about the advantages and disadvantages of an innovation, it is likely that attitudes will become more relevant for adoption decisions (see Rogers, 2003). In this case, the theory of planned behavior might be a useful framework to understand farmers' decisions as it assumes that attitudes are one of the main antecedents of individual behavior (Ajzen, 1985, 1991; Steg and Vlek, 2009). The impact of farmers' attitudes on their decision to adopt or reject could then quantitatively be tested by conducting discrete choice experiments. In this study, it was not possible to identify whether or not individuals truly collected more information, let

alone ultimately adopted the relevant practices. Thus, future empirical studies need to conduct longitudinal studies. By following farmers over several years, it would be possible to explore actual behavior. Longitudinal studies or experiments could also help to provide further support of causal relationships between internal and contextual factors in the domain of farmers' decision making.

Moreover, the sample may have suffered from self-selection bias because only 35% of contacted farmers were willing to participate in the study. Thus, the results could be different for those farmers who did and did not participate, influenced by altruism or trust in research institutions. As a result of such self-selection and the relatively small sample size of 96 famers, it cannot be assumed that the sample is fully representative of German fruit and vegetable farmers. Moreover, environmental values and beliefs about Bioeconomy practices might vary across regions and sectors according to the culture shared by farmers from generation to generation (Schultz and Zelezny, 1999) and, e.g., according to national policy contexts (Prokopy et al., 2015). As this is the first study that applies the VBN framework to the Bioeconomy domain, future studies would be highly desirable to replicate the results with other Bioeconomy practices and in other countries.

Finally, the more exploratory character of this study also leads to two limitations. First, the items used to form measures of VBN variables are translated from other domains and thus applied to the agricultural context for the first time. Also, given that additional indicators have been created to capture farmer beliefs about appropriate contexts for the future valorization of by-products, convergent validity tests are still missing. Second, although the traditional VBN model was enlarged with more relevant variables, the results might still be affected by omitted-variable bias. For example, farmers' decision to gather more information about the valorization of by-products might also be influenced by social norms (Zeweld et al., 2017). For these reasons, future research needs to validate the measurement and structural models of this study by using a larger sample size and other examples of practices in the context of the Bioeconomy.

2.5.2 Policy and managerial implications

This study has three major implications for policy makers and managers who aim to foster the diffusion of novel Bioeconomy practices among farmers. First, the findings indicate that farmers who are more altruistic, aware of environmental consequences, open to change, and with a stronger ecological worldview are more likely to be interested in valorizing by-products. These characteristics can thus be used to develop a profile of the farmers who are most likely

motivated to collect more information, and therefore potentially to adopt novel practices. In this vein, both policy initiatives and market-entry strategies are likely to be more promising if they target farmers with characteristics matching this profile. For example, farmers who have already adopted organic farming practices are shown to be more driven by social and moral concerns (Mzoughi, 2011), while those farmers who have already implemented innovative practices are also generally more open to change (Kemp et al., 2014). Therefore, organic and innovative farmers could act as beneficial target groups for identifying lead users who might be more willing to implement novel practices related to the valorization of by-products (Hippel, 1986) and/or act as "opinion leaders" to influence their fellow colleagues and communities to adopt these practices (Case, 1992; Rogers, 2003).

Second, although values and beliefs are relatively stable across time and context, interventions to, e.g., strengthen farmers' openness to change, altruism, and ecological worldviews could help to stimulate interest in agricultural practices aimed to foster the Bioeconomy. One possibility to cultivate openness to change and pro-environmental values among farmers might be to organize public-private partnerships and workshops in which people with different perspectives discuss sustainability issues and novel agricultural practices (Ngutu and Recke, 2006; Carraresi et al., 2018; Luís et al., 2018)). More fundamentally, schools and universities need to offer environmental education programs to influence internal beliefs (Pooley and O'Connor, 2000). For instance, outdoor activities such as hiking and camping have been shown to foster an increased perceived connectedness with nature, and thereby promoting a more ecological worldview (Schultz, 2000).

Third, the results show that farmers are more likely to be interested in the valorization of by-products if they believe that this practice effectively reduces environmental threats. Therefore, any companies who want to convince farmers to participate in the Bioeconomy transition need to not only communicate the financial benefits but also establish the broader environmental relevance of these practices. In this context, greater information about the beneficial environmental impact of novel practices throughout the supply chain (e.g. by means of a life-cycle assessment) could serve as both valuable information and additional motivation for farmers to undertake the necessary changes.

2.5.3 Concluding remarks

In sum, the results of this study indicate that the VBN theory is a relevant framework for the agricultural domain to predict farmers' interest in the valorization of horticultural by-products. Actually, the findings point towards the existence of an interaction between an internal ecological worldview and the perception of external conditions such as future environmental policies and technology developments. Thus, internal beliefs are potentially relevant by signaling how farmers perceive both the external world and how they evaluate the suitability of conditions for the implementation of practices aimed to foster the Bioeconomy. As a result, this study underlines the importance of pro-environmental beliefs for the transition towards a bio-based economy and highlights them as an interesting avenue for further research in this domain.

3 The impact of systems thinking on consumer intention to buy bio-based products

"The major problems in the world are the result of the difference between how nature works and the way people think"

Gregory Bateson (1972)

Chapter 3 answers the following research question:

RQ 3: Does systems thinking affect consumer intention to purchase bio-based products?

RQ 4: How does systems thinking relate to consumers' values, ecological worldview, beliefs and norms?

This chapter is based on the following publication:

Wensing, J., Baum, C., Carraresi, L. and Bröring, S. (*under review*). The impact of systems thinking on consumer intention to buy bio-based products.

3.1 Introduction

Complex environmental issues such as climate change and resource depletion are increasingly challenging for the well-being of humans, animals and the biosphere (Meadows et al., 2004). Various scholars argue that one of the major causes of these environmental problems is the failure to appreciate all the manifold ways in which human activity affects the complex and dynamic nature of natural systems (Liening, 2013; Randle and Stroink, 2018). In order to shift to a more sustainable system of production and consumption, it would be helpful for people to more deeply reflect on their actions and to adopt a systems-thinking perspective which more fully takes into account the negative consequences of their own behavior (Meadows et al., 1972; National Research Council, 2012; Davis and Stroink, 2015; Lezak and Thibodeau, 2016).

Systems thinking (ST) is conceptualized as a worldview which entails cognitive beliefs about the complex and interconnected nature of reality (Randle and Stroink, 2018). In the environmental domain, the importance of ST has been increasingly recognized starting with the Club of Rome's report "*The Limits to Growth*" (Meadows et al., 1972). Recently, ST has been pointed to as a crucial ingredient for achieving progress on the Sustainable Development Goals (SDGs), such as no poverty and the elimination of hunger (Nature Editorial Board, 2020). More generally, Meadows (2008) argues that, by highlighting the relationship between the structure of systems and individual behavior, systems thinking can offer a tool to help people better grasp their environmental impact, in a stronger sense, and thus their broader role within complex systems.

Therefore, ST is also expected to be an important driver for the transition towards a bio-based economy, whereby innovative products and processes are utilized to substitute fossil fuels and materials with renewable bio-based ones (Urmetzer et al., 2020). The central idea here is that people who are more aware of the social and environmental consequences of consuming fossil fuels are more likely to prefer bio-based cosmetics, detergents or plastics over their fossil-based alternatives (Schwartz, 1977; Urmetzer et al., 2020). Prior studies indicate that an ST mindset is also associated with higher perception of climate-change risks (Lezak and Thibodeau, 2016), as well as a belief that climate change is happening (Ballew et al., 2019). Given the current lack of evidence, and indeed research, on the effect of ST on the willingness to purchase bio-based products however, it is not possible to state more explicitly how and for what reason systems thinking is relevant in the context of the Bioeconomy. What is more, despite growing interest in ST, there is little empirical work on the particular mechanisms through which pro-environmental

behavior is promoted (Davis and Stroink, 2015; Lezak and Thibodeau, 2016; Davis et al., 2017; Ballew et al., 2019). In other words, does systems thinking merely offer a substitute for other more familiar factors, such as values and norms, or is its importance for consumer behavior and purchasing decisions independent to a certain extent?

Hence, this paper explores the relevance of ST for consumer intentions to purchase bio-based products, and what is more the mechanisms that underlie such purchasing decisions . In order to close these research gaps, we conducted an online survey with 446 US consumers where we consider the effectiveness of an ST-motivated treatment in which participants are asked to enumerate the consequences of their consumption behavior. In addition, given the relative novelty of ST in this context, we further incorporate and consider the importance of other factors, notably, pro-environmental values, environmental worldviews, belief, and norms (e.g. Stern et al., 1999; Dunlap et al. 2000).

As a result, the contributions of this study are twofold. First, this is to our knowledge the first study to investigate the impact of ST as a driver for consumer behavior in the bio-economy context. Second, this study advances our understanding of how ST relates to pro-environmental motivations, that is, whether this factor offers unique explanatory potential alongside values, worldviews, beliefs and norms (Davis and Stroink, 2015; Lezak and Thibodeau, 2016; Thibodeau et al., 2016; Davis et al., 2017; Ballew et al., 2019). By means of mediation analysis, moreover, this study specifically provides an empirical illustration of the mechanism by which ST influences consumer behavior. Such insights can be employed by policy-makers and marketers to better customize their strategies to increase consumption of bio-based products.

The article is organized as follows: the next section summarizes the literature and derives hypotheses about the relationship between consumer intention to buy bio-based products on the one hand, and the interplay of ST, values, beliefs, and norms on the other. The methods section outlines the experimental procedure, including the treatment that is used, our use of PROCESS for the (serial) mediation analysis, and the sample characteristics. Next, we establish the ST-motivated treatment was effective and present the results of the mediation analyses. Finally, we derive theoretical and practical implications for our research and discuss limitations before giving directions for future research.

3.2 Literature review

ST provides a framework to see a system - such as the ecosystem – as a set of interconnected elements characterized by stabilizing and reinforcing chains of causal connections (Meadows, 2008). Therefore, individuals employing ST are more likely to be aware of the environmental impacts of their behaviors, as well as to make relevant changes to act in a more pro-environmental fashion (Davis and Stroink, 2015). In consumer research, the ability and tendency to better grasp the consequences of one's behavior is called perceived consumer effectiveness (PCE; Antil and Bennett, (1979)). Prior studies show that those with higher perceived consumer effectiveness are more likely to engage in sustainable purchase behavior, as they are convinced that this can help to alleviate environmental threats (Coelho et al., 2017; Hooge et al., 2017; Joshi and Rahman, 2019). An ST perspective, in contrast, reflects not only PCE, but also includes more general beliefs that enable people to create multi-level change towards a more sustainable future (Nature Editorial Board, 2020; Urmetzer et al., 2020). However, empirical evidence for the relationship of ST and sustainable purchasing behavior is still missing. Moreover, it is unclear whether a more generally relevant sense of complexity and interconnectedness can be triggered. Thus, we explore the effectiveness of a treatment for activating an ST perspective which, in turn, affects consumer intention to buy bio-based products.

H1: The effect of the treatment on consumer intention to buy bio-based products is mediated by systems thinking.

However, the nature of the relationship between ST and pro-environmental behavior is still unclear. Referring to the environmental psychology domain, potential motivations for pro-environmental behavior are currently studied from different theoretical perspectives: 1) altruistic values (Schwartz, 1977; Rokeach, 1980; Stern and Dietz, 1994), 2) ecological worldview (Stern et al., 1995a; Dunlap et al., 2000) and 3) moral norms (Schwartz, 1977; Davis and Stroink, 2015). Values and worldviews are assumed to serve as antecedents for rather specific beliefs which, in turn, shape moral norms to engage in pro-environmental behavior (Stern et al., 1999).

Values are believed to evolve during socialization and to be rather stable in adulthood (Rokeach, 1980). It is assumed that value orientations direct people's attention towards objects they value and, thus, shape their attitudes towards these objects as well as guide their behavior (Rokeach, 1980; Stern and Dietz, 1994; Nordlund and Garvill, 2002). Prior studies found that social-altruistic

and biospheric-altruistic value orientations, reflecting concern for the wellbeing of other individuals, species and the biosphere, seem to drive pro-environmental behavior (Stern et al., 1995b; Nordlund and Garvill, 2002; Steg, 2016; Ünal et al., 2018; Wensing et al., 2019). In contrast to values, ST is defined as a worldview with general beliefs about the nature of reality (Davis and Stroink, 2015). Stern et al. (1995a) assume that general beliefs may evolve as a result of a combination of existing value orientations and individual experiences over the life course. Hence, we assume that altruistic values serve as an antecedent of ST as people with altruistic values focus on the consequences of their behavior for others and the biosphere (Steg, 2016). Also, prior research indicates that altruism has a positive effect on consumer intention to purchase bio-based products (Klein et al., 2019). Thus, this relationship between altruistic values and consumer intention to purchase bio-based products might be explained through ST. Therefore, the following hypothesis is deduced:

H2: The relationship between altruistic values and consumer intention to buy bio-based products is mediated by systems thinking.

A worldview reflects general beliefs about reality in a specific domain of life. In contrast to values, worldviews are less stable and can be questioned in terms of their accuracy in understanding reality (Stern et al., 1995b). The most widely studied worldview dealing with the relationship between humans and the environment is the new ecological paradigm (NEP) (Dunlap et al., 2000). The NEP reflects the beliefs that humans are part of the natural system which is very delicate with limited resources (Stern et al., 1995a; Dunlap et al., 2000). In contrast to the NEP, ST not only reflects specific cognitive beliefs about the relationship between humans and the ecological system but also includes domain-general beliefs about the economic and social system (Davis and Stroink, 2015; Randle and Stroink, 2018). Thus, it is argued that from a theoretical perspective an ecological paradigm might be a component of a general systemic worldview (Davis and Stroink, 2015).). Indeed, studies show that ST share a positive relationship with the NEP (Davis and Stroink, 2015; Ballew et al., 2019). A recent study even found that the NEP fully mediates the relationship between ST and more concrete global warming beliefs (Ballew et al., 2019).

In addition, prior studies found a positive relationship between NEP and pro-environmental purchasing behavior (Stern et al., 1999; Cordano et al., 2003; Yi, 2019). Based on these findings, we hypothesize:

H3: The relationship between systems thinking and consumer intention to buy bio-based products is mediated by an ecological worldview.

Personal norms are defined as feelings of moral obligations to engage in specific behaviors (Schwartz, 1977). uses the construct of personal norms to explain altruistic behavior. Applied to the environmental domain, the NAM postulates that moral obligations to act pro-environmentally are activated when individuals become aware of the consequences of their behavior for the environment (problem awareness or PA beliefs) and believe that their actions can adverse these consequences (outcome efficacy or OE beliefs). The NAM was found to successfully explain a wide range of pro-environmental behaviors (Guagnano et al., 1995; Nordlund and Garvill, 2002; Abrahamse et al., 2007). To date, no empirical study investigated the relationship between ST and personal norms to engage in pro-environmental behavior. However, prior studies looked at how ST relates to individual concerns about environmental consequences which the NAM models as the precondition of moral obligations to act pro-environmentally (Davis and Stroink, 2015; Lezak and Thibodeau, 2016; Ballew et al., 2019). More specifically, a ST mindset was found to be associated with the perception of climate change risks (Lezak and Thibodeau, 2016) and the general belief that climate change is happening (Ballew et al., 2019). Davis and Stroink (2015), moreover, argue that concern about environmental consequences[1] mediates the relationship between systems thinking and pro-environmental behaviors. Consequently, it is assumed:

H4: The relationship between systems thinking and consumer intention to buy bio-based products is mediated by problem awareness, outcome efficacy and personal norm.

Figure 3.1 provides an overview of the hypothesized mediation models in this study.

[1] Davis and Stroink (2015) define this variable as ‘biospheric values’. However, based on Schwartz (1977) we define individual concerns about consequences of environmental problems as ‘beliefs’.

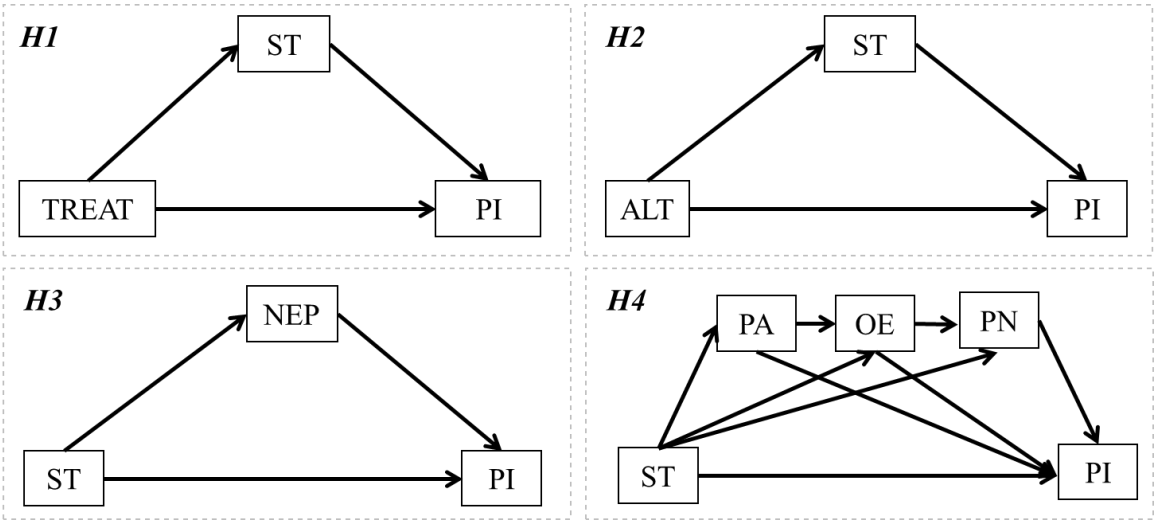

Figure 3.1. Overview of hypothesized mediation models.

3.3 Methods

This study uses an online survey with a between-subject design approach to assess whether pro-environmental values, worldview, belief and norms explain the relationship between ST and consumer intention to purchase bio-based products.

3.3.1 Participants

Data was collected in March 2019 in cooperation with a market research company. Due to the lack of empirical studies about the adoption of bio-economy innovations in the US, we chose to target consumers in this context, focusing on those ≥18 years. Moreover, the measure to assess ST is currently only available in English language (Davis and Stroink, 2015) and a pre-test with the same measure translated in German produced unreliable results. Quotas were set on age and gender in accordance with current US data from Statista. In total, 697 consumers filled out the survey; however, we excluded 251 participants who failed to appropriately respond to the trap question (*For quality purposes, please click "somewhat disagree"*)[2]. A total of 446 respondents were employed for the statistical analysis.

[2] If the participants did not click *"somewhat disagree"*, we assumed they did not pay attention to the survey questions and, thus, excluded them from the dataset.

3.3.2 Procedure

The online survey was organized in five parts as depicted in Figure 3.2.

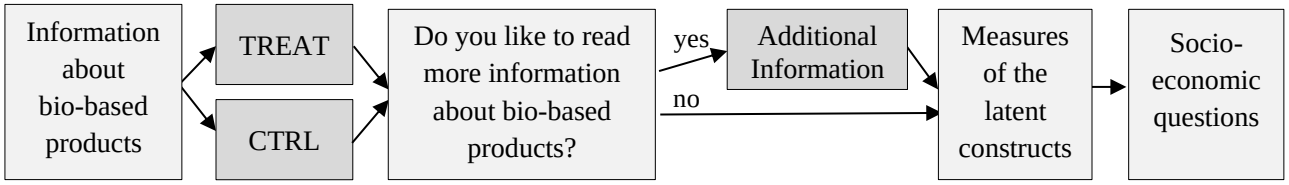

Figure 3.2. Overview of experimental survey procedure.

The first section consisted of an informative text about bio-based products as consumers are generally not familiar with these type of products (Sijtsema et al., 2016). The text provides participants with a definition and several examples of bio-based products (see Appendix E). In the second section, participants were randomly assigned to the control or to the treatment group. Respondents in the treatment group were provided with a treatment and the control group simply continued with the third part of the survey. More details regarding the procedure of the treatment are presented in section 3.3.3. In the third part, participants could voluntarily choose to read more information about bio-based products (see Appendix F). This opportunity is given to the participants to reflect the reality in which some consumers actually collect more information to form an attitude towards novel products and others do not (Rogers, 2003). The next part consisted of several measures of the latent constructs which are presented in section 3.4. In the last section, participants were asked about socio-demographic factors such as education level, employment status and household income.

3.3.3 Treatment

Participants were randomly assigned to the treatment group (hereafter TREAT) or to the control group (hereafter CTRL). In TREAT, they were asked to list as many consequences as possible 1) related to their buying decisions and 2) if they were to (hypothetically) purchase bio-based products more frequently. This task was intended to activate a ST perspective for consumers, by drawing attention to the interconnectedness between their own behavior and external consequences (Hmelo-Silver et al., 2017; Cox et al., 2019). In CTRL, participants did not receive any task and simply continued with the survey. A manipulation check indicates that the treatment did motivate ST, with TREAT participants reporting higher values of ST compared to those in CTRL (M_{TREAT} = 4.41, *S.D.* = 0.62 vs. M_{CTRL} = 4.27, *S.D.* = 0.56, $D(446) = 1.35$, $p = 0.05$).

3.3.4 Measures

The participants completed several validated measures from the literature to measure purchase intention (Ajzen, 1991), systems thinking (Davis and Stroink, 2015), altruism[3] (Stern et al., 1999; Groot and Steg, 2007), ecological worldview (NEP, Dunlap et al., 2000) and the NAM-variables (Groot and Steg, 2007; Ünal et al., 2018). Items employed a 7-point scale, from 1 = strongly disagree to 7 = strongly agree[4]. The results of the internal reliability analyses indicate that all measures show acceptable to good reliability. Table 3.1 gives an overview of these measures by presenting example items and Cronbach's Alpha values.

Table 3.1. Overview of measures of the questionnaire.

Measure	Item(s)	Cronbach's Alpha
Purchase intention (PI)	4 items; e.g. *If I had to choose, I would buy bio-based instead of fossil-based products*.	0.914
Systems thinking (ST)	15 items; e.g. *Seemingly small choices can ultimately have major consequences.*	0.736
Altruism (ALT)	8 items; *How important are the following values for you as a guiding principle in your life?* e.g. *Unity with nature*	0.884
New ecological paradigm (NEP)	8 items; e.g. *The balance of nature is very delicate and easily upset.*	0.853
Problem awareness (PA)	6 items; e.g. *I am concerned about CO2 emissions resulting from manufacturing fossil-based products.*	0.911
Outcome efficacy (OE)	6 items; e.g. *My personal purchasing decisions can contribute to the reduction of CO2 emissions.*	0.882
Personal norm (PN)	5 items; e.g. *I feel a personal obligation to buy more bio-based products.*	0.925

3.3.5 Data analysis

To test the hypotheses, we fitted mediation models using the PROCESS macro for SPSS developed by Hayes (2018). Mediation generally assumes that a predictor variable (X) affects a second variable (M) that, in turn, affects the outcome variable (Y), so that M mediates the relationship

[3] In line with Stern et al. (1999), we model social and biospheric value orientations jointly as altruistic values.

[4] The items to measure Altruism are scaled from 1 = Not at all important to 7 = Extremely important

between X and Y. The regression-based procedure developed by Hayes (2018) allows us to estimate both the direct effects between X, M and Y and the indirect effect of X through M on Y. The indirect effect coefficient is represented by the product of the two path coefficients between X and M, and M and Y. In this study, the first mediation model assesses if the effect of *TREAT* (X) on *PI* (Y) is mediated by *ST* (M). The second model explores the extent to which the effect of *ALT* (X) on *PI* (Y) can be explained by *ST* (M). Third, we assess if *NEP* (M) explains the impact of *ST* (X) on *PI* (Y). Finally, the fourth model explores if the relationship between *ST* (X) and *PI* (Y) is mediated by *PA*, *OE* and *PN* (M). The significance of the indirect effect is tested by using the non-parametric bootstrapping technique which generates a distribution of 10.000 estimates. If the value related to the null hypothesis falls outside the lower level (*LLCI*) and upper level (*ULCI*) of the 95 % confidence interval, the indirect effect is assumed to be non-zero (Hayes, 2018).

The variable consumer intention to purchase bio-based products (PI) represents the outcome variable in all four estimated mediation models. Thus, before testing the models, we analyzed the distribution of the outcome variable by using the Kolmogorov-Smirnov test which indicates that PI does not follow a normal distribution, $D(446) = 0.086$, $p = 0.000$. Therefore, we apply a log transformation in order to reduce positive skew (Field, 2013) and use the transformed PI variable in the mediation models.

As the level of PI might also be influenced by other variables not listed in the hypotheses, we also included some covariates. First, we control for the impact of the situation that some participants gathered additional information about bio-based products and others did not. This condition is depicted by a dichotomous dummy-variable taking the value 1 for respondents who gathered more information, and 0 otherwise. Second, the mediation models depicted in H2, H3 and H4 also control for the treatment effect using the dummy variable as described above.

In order to make sure that the predictors in the regression models are not strongly correlated with each other, we also tested for multicollinearity based on the variance inflation factor (VIF). According to Craney and Surles (2002), values higher than 5 indicate strong linear relationships between predictors. In this study, VIF values range between 1.103 and 2.529 suggesting the mediation models are not biased by multicollinearity.

3.3.6 Sample characteristics

A more detailed look at the sample shows that the number of respondents in CTRL (n = 278) is higher than in TREAT (n = 168). The higher dropout rate here could relate to the length of the task in TREAT. In order to ensure that any differences in the treatment groups do not reflect composition effects, however, we conducted chi-square tests for each socio-demographic factor to see if the respective means differ. Table 3.2 reports the socio-demographic characteristics for both respondents in CTRL and TREAT, as well as results of the chi-square tests.

Table 3.2. Sample Characteristics in percentages.

Variable	CTRL	TREAT	Chi square Test Statistics
Gender			
Female	0.60	0.62	$X^2 = 2.00, p = 0.37$
Male	0.40	0.37	
Divers	0.00	0.01	
Age			
18 − 24 years	15.47	13.10	$X^2 = 1.51, p = 0.91$
25 − 34 years	21.94	22.62	
35 − 44 years	16.91	14.29	
45 − 54 years	9.35	10.71	
55 − 65 years	15.83	18.45	
Over 65 years	20.50	20.83	
Education			$X^2 = 0.20, p = 0.98$
No School completed	3.24	2.98	
High School Diploma	36.69	38.69	
Practical Training	25.90	25.59	
University Degree	34.17	32.74	
Household yearly income			$X^2 = 2.30, p = 0.51$
Up to $ 29,999	35.97	29.17	
$ 30,000 – 59,999	33.45	38.09	
$ 60,000 – 89,999	18.35	19.05	
Over $ 90,000	12.23	13.69	
No. of Observations	278	168	

The gender distribution in both CTRL and TREAT indicates that more female than male respondents participated. As females are usually responsible for household purchases (Flagg et al., 2014), we do not consider the distribution to be problematic for this study. Moreover, our sample is slightly younger than the national average, notably lacking respondents between 45-54 years (Statista, 2018b). In terms of educational attainment, our sample is nearly proportionate to the US as a whole with regard to those with a university degree (Statista, 2019c), though it is over-representative at lower levels of annual household income (Statista, 2019b). Finally, the results of the chi-square tests suggest that the null hypothesis of equality between treatment groups cannot be rejected at the 5% significance level. This implies that the demographic variables are similarly distributed in CTRL and TREAT. Descriptive results for both respondents in CTRL and TREAT are presented in Appendix G.

3.4 Results

To investigate the hypotheses, we fit four mediation models following the approach specified by Hayes (2018). The mediation effects are tested using the bootstrapping technique with 10.000 bootstrap samples. All estimated mediation models also include the covariates *AGE*, *TREAT* and *INFO* as described above. The results of the mediation models are presented in Table 3. Details on the results for the covariates are presented in Appendix H.

First, we assess if the effect of *TREAT* on *PI* is mediated by *ST* (H1). The effect of *TREAT* is tested by using a dummy variable taking the value 1 for respondents in the treatment group, and 0 otherwise. Results show that *TREAT* has a significant effect on *ST* and, in turn, *ST* is positively associated with *PI*. Although the direct effect of *TREAT* on *PI* is not significant, the analysis indicates that there is a significant indirect effect of *TREAT*, mediated through *ST*, on *PI*. The mediation model predicts significant variance in *PI*, $R^2 = 0.16$, $F = 28.51$, $p = 0.00$.

Second, we explore the relationship between *ALT*, *ST* and *PI* (H2). Results indicate that *ALT* significantly predicts *ST*, which is, in turn, significantly related to *PI*. The direct effect of *ALT* on *PI* is also significant. Moreover, *TREAT* served as a significant covariate for *ST* and *INFO* for *PI*. Most importantly, the analysis of the indirect effect suggests that the relationship of *ALT* and *PI* is mediated by *ST*. This mediation model also significantly predicts variance in *PI*, $R^2 = 0.23$, $F = 32.06$, $p = 0.00$.

Table 3.3. Results of the mediation models.

Hypotheses		Coeff. (SE)	St. Coeff.	t	p-value	LLCI - ULCI
H1	TREAT → ST	0.15 (0.06)	**0.25**	2.55	**0.01**	0.03 – 0.2
	ST → PI	0.07 (0.01)	**0.35**	7.93	**0.00**	0.06 – 0.09
	TREAT → PI	0.01 (0.01)	0.10	1.07	0.29	-0.01 – 0.03
	TREAT → ST → PI	0.01 (0.01)	**0.09**	-	-	**0.00 – 0.02**
H2	ALT → ST	0.33 (0.03)	**0.44**	10.35	**0.00**	0.26 – 0.39
	ST → PI	0.05 (0.01)	**0.22**	4.74	**0.00**	0.03 – 0.07
	ALT → PI	0.04 (0.01)	**0.28**	6.00	**0.00**	0.03 – 0.06
	ALT → ST → PI	0.02 (0.03)	**0.10**	-	-	**0.05 – 0.15**
H3	ST → NEP	0.78 (0.06)	**0.51**	12.50	**0.00**	0.66 – 0.90
	NEP →PI	0.04 (0.01)	**0.29**	5.86	**0.00**	0.03 – 0.05
	ST → PI	0.04 (0.01)	**0.20**	4.07	**0.00**	0.02 – 0.06
	ST → NEP → PI	0.03 (0.01)	**0.15**	-	-	**0.02 – 0.05**
H4	ST → PA	1.00 (0.09)	**0.47**	11.34	**0.00**	0.83 – 1.17
	ST → OE	0.25 (0.07)	**0.14**	3.78	**0.00**	0.12 – 0.38
	ST → PN	-0.03 (0.08)	-0.01	-0.38	0.71	-0.19 – 0.13
	PA → OE	0.53 (0.03)	**0.64**	16.74	**0.00**	0.47 – 0.59
	PA → PN	0.41 (0.05)	**0.39**	8.44	**0.00**	0.31 – 0.50
	PA → PI	0.01 (0.01)	0.10	1.72	0.09	-0.00 – 0.02
	OE → PN	0.52 (0.06)	**0.42**	9.24	**0.00**	0.41 – 0.63
	OE → PI	0.03 (0.01)	**0.28**	4.81	**0.00**	0.02 – 0.05
	PN→ PI	0.02 (0.01)	**0.25**	4.51	**0.00**	0.01 – 0.04
	ST → PI	0.02 (0.01)	**0.09**	2.05	**0.04**	0.00 – 0.04
	ST→PA→OE→PN→PI	0.06 (0.01)	**0.26**	-	-	**0.00 – 0.01**

Note: St.Coeff. = Standardized Coefficients, SE = Standard Error, LLCI = Lower Level of 95 % Confidence Interval; ULCI = Upper Level of 95 % Confidence Interval

Third, we assess how *ST*, *NEP* and *PI* relate to each other (H3). According to the results, *ST* significantly predicts *NEP*, which, in turn, significantly predicts *PI*. *ST* also has a significant direct effect on *PI* and a mediation effect of *ST* on *PI* through *NEP* cannot be rejected as the indirect effect is significant. The mediation model significantly predicts variance in *PI*, $R^2 = 0.23$, $F = 32.06$, $p = 0.00$.

Fourth, we explore the relationship between *ST, PA, OE, PN* and *PI* (H4). The results suggest that *ST* significantly predicts *PA* and *OE*, but not *PN*; *PA* significantly predicts *OE* and *PN*, but not *PI*; *OE* significantly predicts *PN* and *PI*; and *PN* significantly predicts *PI*. Estimating the effects of the covariates, we find that *INFO* is positively associated with *PA* and *PI*. Moreover, *ST* also has a significant direct effect on *PI*, and the total indirect effect of *ST* on *PI* through *PA, OE* and *PN* is significant. The whole model significantly predicts variance in *PI*, $R^2 = 0.41$, $F = 50.39$, $p = 0.00$.

3.5 Discussion

The present research aims to explore the relationship between systems thinking and consumer intention to purchase bio-based products. Moreover, we investigate if altruistic values, an ecological worldview and personal norms play a role in this relationship. Based on the findings of this study, we are able to make several theoretical and practical contributions which are presented in the following.

3.5.1 Theoretical contributions

The first contribution of this study is that it provides empirical evidence of a positive relationship between systems thinking and purchase intention of bio-based products. This finding is in line with prior research showing that systems thinking affects pro-environmental decision making and behavior (Davis and Stroink, 2015; Lezak and Thibodeau, 2016). More importantly, the results of this study indicate that a task in which consumers list the consequences of their own consumption behavior is successful in activating a systems thinking perspective which, in turn, affects their purchase intention. This insight advances the understanding of how systems thinking can be activated as current research mainly focuses on using linguistic or visual metaphors (Thibodeau et al., 2017). However, it is important to note that although results show a strong effect of the treatment on systems thinking, the indirect effect of the treatment on purchase intention seems to be rather small.

Second, the results of this research demonstrate that the relationship between altruism and purchase intention is mediated by systems thinking. The reason for this effect might be that altruistic people base their decisions on consequences for other people and the biosphere (Steg, 2016) which potentially facilitates a systemic worldview. This insight is relevant as it provides an explanation for prior findings about a positive association between altruism and pro-environmental behavior

(e.g. Steg, 2016; Klein et al., 2019). In contrast to our results, Davis and Stroink (2015) found that biospheric values serve as a mediator between systems thinking and pro-environmental behavior. However, Davis and Stroink (2015) modelled biospheric values as individual concerns about consequences for the environment. However, we also tested the sequence suggested by Davis and Stroink (2015) which also fitted to the data. Hence, future studies need to explore the causal direction of the relationship between altruism and systems thinking into more detail.

Third, this study finds evidence that systems thinking positively influences an ecological worldview which, in turn, affects consumer intention to purchase bio-based products. This result is in line with recent findings from Ballew et al. (2019). Consequently, systems thinking might encourages people to engage in pro-environmental behavior because a systemic worldview is associated with an ecological worldview (Davis and Stroink, 2015; Randle and Stroink, 2018). Ballew et al. (2019) even make assumptions about the causal direction and argue that systems thinking is the basis for the development of an ecological worldview. However, this assumption requires further investigation.

Fourth, findings of this study indicate that the relationship between systems thinking and intention to buy bio-based products is mediated by consumers' problem awareness, outcome efficacy and personal norms. More specifically, the results of the mediation model show that systems thinking is strongly associated with consumers' problem awareness and outcome efficacy, but does not directly influence personal norms. However, in line with the norm activation model (NAM) based on Schwartz (1977), the results also indicate that outcome efficacy and problem awareness activate personal norms which, in turn, encourage consumer purchase intention. These insights are relevant as they advance knowledge about the preconditions of the NAM which is widely used to predict pro-environmental behavior (Schwartz, 1977; Harland et al., 2010; Börger and Hattam, 2017; Ünal et al., 2018).

Finally, the overall finding of our study is that the integration of systems thinking into existing models from environmental psychology literature could improve the explanation of consumer intention to buy bio-based products. Synthesizing our results, we propose an overarching model to explain purchase intention based on the mediation model depicted in H4. This model proposes that systems thinking positively influences consumer problem awareness and outcome efficacy which, in turn, affect consumer personal norms and purchase intention. Compared to the other mediation models depicted in H2 and H3, this model achieves the highest predicted variance in consumer

purchase intention. Moreover, statistical tests indicate that expanding the model with altruism and NEP does not further increase the predicted variance. Consequently, we assume that a model which combines systems thinking with the NAM fits our data best in explaining consumer intention to purchase bio-based products. However, this model still needs empirical evidence from other domains.

3.5.2 Managerial and policy contributions

The transition towards a bio-based economy strongly depends on consumer willingness to purchase novel bio-based products (Golembiewski et al., 2015). Hence, understanding the precondition of consumer intention to buy bio-based products can help policy-makers and marketers to develop appropriate strategies to increase the demand. In this vein, the present research makes three relevant practical contributions.

First, this study indicates that consumers generally intend to purchase bio-based products. This is in line with prior consumer studies in the bio-economy domain (Scherer et al., 2018a; Klein et al., 2019). Although data about real consumer choices are still missing, these findings provide an indication for policymakers and companies planning to invest in the development of bio-based products.

Second, the results of this research provide empirical evidence that systems thinking is a cognitive paradigm playing a pivotal role in the transition towards a bio-based economy. Consequently, systems thinking would need to be included among the subjects taught in schools and universities (Urmetzer et al., 2020) in order to start a cultural transition from the young generations. Indeed, previous studies show that systems thinking is generally malleable by educational interventions, e.g. role-plays (Sterman et al., 2015) or conceptual representations and diagrams (Hmelo-Silver et al., 2017; Cox et al., 2019).

Third, the success of the treatment in the present study shows that a systems-thinking mindset can be activated by a subtle prime. For marketers of bio-based products, this means that drawing consumers' attention to the beneficial environmental consequences of bio-based products might strengthen their purchase intention. In practice, this could be achieved by pro-environmental product labels or informative brochures (Schubert, 2017).

3.5.3 Limitations and implications for further research

The present research has four main limitations which, in turn, highlight avenues for further research. First, this study was carried out with US consumers, so that the results are not generalizable to other countries. Prior studies that explore the impact of systems thinking are also based in the US or in Canada (Davis and Stroink, 2015; Ballew et al., 2019). Thus, similar studies need to be conducted in other parts of the world in order to validate and compare the findings. Moreover, the benefits of ST for achieving a more sustainable future also need to be explored beyond consumption behavior. For example, future studies could explore the impact of a ST-motivated workshop on sustainability-oriented decision making of researchers, policymakers and industry representatives.

Second, the sample of US consumers might be biased as more respondents dropped out of the treatment group than out of the control group. These drop-outs might have been systematic and, thus, confounded the results of this study. However, also in practice, the treatment can only be successful if the participants are willing to conduct the task. Therefore, those people who dropped out would probably also avoid this kind of reflection about the consequences of their behavior in real life. However, this assumption still requires empirical evidence. To tackle this issue, further studies should therefore employ control 'treatments' that demand similar time and cognitive effort to the main treatment.

Third, the variables in this study were measured using self-reports of the respondents which raises some issues. For example, the observed relationships between the variables might be overestimated due to common method variance. Next, we only measured participants' intention to purchase bio-based products, which is assumed to be a good predictor of actual behavior, but the potential for bias still exists (e.g. Morrison, 1979). Moreover, self-report measures potentially suffer from social desirability bias. Although Milfont (2009) only found a small effect of social desirability on self-reported environmental attitudes and behaviors, future studies need to tackle this issue. For example, systems thinking and pro-environmental beliefs could be measured using decision-making tasks (e.g. Thibodeau et al., 2016), implicit-association tests (e.g. Panzone et al., 2016) or neuropsychological measures (Fulmer and Frijters, 2009).

Fourth, based on the hypotheses we formulated, this study explored specific pathways through various mediation models. However, due to the correlational nature of the study design, we are not able to draw fully causal inferences based on our data. Further studies should therefore consider an

experimental design that provides the participants with different tasks or information to activate relevant variables such as altruism or problem awareness (e.g. Steg and de Groot, 2010). Thereby, the causal mechanisms by which systems thinking promotes pro-environmental behavior can be explored into more detail.

4 The impact of green nudges on consumer valuation of bio-based plastic packaging

"Unless there is an obvious reason to do otherwise,
most of us passively accept decision problems as they are framed […]"

Daniel Kahneman (2011)

Chapter 4 answers the following research questions:

RQ 5: Which green nudges increase consumer willingness to pay for bio-based plastic packaging?

RQ 6: How do individual differences in consumers' cognitive styles impact the effectiveness of green nudges?

This chapter is based on the following publication:

Wensing, J., Caputo, V., Carraresi, L. and Bröring, S. (2020). The effects of green nudges on consumer valuation of food with bio-based plastic packaging. *Ecological Economics*, 178: 106783.

4.1 Introduction

Plastic packaging is increasingly associated with negative environmental consequences including fossil fuel usage, high amounts of waste and environmental pollution (European Commission, 2018). As such, bio-based plastic packaging produced on the basis of renewable resources is gaining attention as the more sustainable alternative with the potential to reduce greenhouse gas emissions and to alleviate climate change (Bos et al., 2010; van den Oever et al., 2017). To date, the overall market share for bio-based plastic packaging still remains small (European Bioplastics, 2018). The reason for the small market share might be that research and development costs as well as low fossil oil prices make it currently difficult for bio-based plastic packaging to compete with conventional alternatives (Carus et al., 2014; European Bioplastics, 2019). However, an increasing market demand of bio-based plastic packaging could facilitate more efficient large-scale production systems and, in turn, lower prices (Cutter, 2006; Pan et al., 2016; European Bioplastics, 2019). Thus, scholars point out that strategies are needed to raise consumer awareness and to increase their willingness to switch to bio-based packaging alternatives (Kainz, 2016; Herbes et al., 2018). In this case, recent advancements in behavioral economics and environmental psychology identified green nudges as promising tools to increase consumers' demand for pro-environmental products (Kahneman, 2003; Thaler and Sunstein, 2008; Venkatachalam, 2008; Schubert, 2017). However, there is a lack of empirical evidence for the success of green nudges in the case of increasing the demand of bio-based plastic packaging.

This paper thus integrates insights from environmental psychology into random utility models to explore which green nudges can be used to influence consumer preferences and willingness-to-pay (WTP) for bio-based plastic packaging. To this end, a discrete choice experiment is conducted where German consumers are asked to choose a preferred alternative among multiple options of cherry tomatoes with varying packaging. We chose German consumers as they are among the heaviest packaging waste producers in the EU with 24.9 kg of plastic packaging per inhabitant in 2016, adding up to a total of 2.05 million tons per year (German Environment Agency, 2018; Eurostat, 2019). With a between-subject design approach, the study also explores if and how consumers' decision-making process is influenced by different green nudges which aim to activate consumers' pro-environmental values, worldview, beliefs, and social norms.

The contribution of this study to the field of ecological economics is twofold. First, we elucidate consumer WTP for food with bio-based plastic packaging. Compared to conventional fossil-based plastic packaging, bio-based plastic packaging is made from renewable biomass (Peelman et al., 2013) and has the potential to reduce greenhouse gas emissions in the production process (European Bioplastics, 2019). To this end, the German government introduced the new Packaging Act (VerpackG) on January 1st, 2019 which urges companies to contribute to the environmental costs of packaging. Therefore, the food industry is becoming increasingly interested in bio-based plastic packaging as a substitute for more conventional packaging (Peelman et al., 2013). In fact, bio-based plastic contains a wide variety of properties that are similar to conventional plastics. This similarity makes bio-based plastics applicable as packaging material for a wide range of food products (Peelman et al., 2013). However, bio-based plastic packaging is more expensive than their fossil-based counterparts (Carus et al., 2014; van den Oever et al., 2017; European Bioplastics, 2019). Hence, it is important to explore how much consumers are willing to pay for bio-based plastic packaging to see if it will be feasible for food companies to implement these products. While some studies investigated consumer perceptions of bio-based plastic packaging (Steenis et al., 2017; Herbes et al., 2018), this is the first study investigating consumer WTP for food with bio-based plastic packaging.

The second contribution is how our results contribute to the behavioral economics and environmental psychology literature by comparing the effectiveness of green nudges aimed to activate pro-environmental values, beliefs, and social norms. Based on empirical insights about human perception and decision-making, nudges are promising tools that modify the situation in which a decision is taken to change people's behavior in a predictable way (Thaler and Sunstein, 2009; Schubert, 2017). Green nudges in particular are interventions which trigger people to engage in environmental behavior (Schubert, 2017). For example, relevant literature suggests nature pictures, informational videos, or normative information in order to encourage consumers to purchase pro-environmental products (Nolan et al., 2008; Steg and Groot, 2010; Hahnel et al., 2014). However, it is not clear which of these green nudges works best to encourage consumers to purchase pro-environmental products. Therefore, our paper aims to compare the impact of green nudges on consumers' WTP for bio-based plastic packaging. Understanding what tools are needed to raise WTP is crucial for food companies and policy makers to expand the market share of bio-based plastic packaging.

The article is organized as follows: the next section summarizes prior research on green nudges. The methods section, which describes the experimental procedure and behavioral treatments, follows. Next, we present the econometric models and results. The final section concludes with practical implications for companies, policy-makers, and for further research.

4.2 Literature review

Green nudges make use of the insight that human decision-making is heavily context dependent by modifying the choice architecture, i.e. the situation in which a decision is taken (Kahneman, 2003; Thaler and Sunstein, 2009; Schubert, 2017). Specific examples are pro-environmental product labels which are assumed to direct people's attention and, thereby, also guide their decision-making (Schubert, 2017). Green nudges might be especially effective when activating internal values, worldviews, beliefs and norms that generally motivate environmental behavior (Schwartz, 1977; Stern et al., 1995b; Schultz, 1999; Nordlund and Garvill, 2002; Steg and Vlek, 2009). The following summarizes potential strategies to activate these internal motivations based on existing empirical studies.

Values are rather stable across time and situations and are not subject to change in the short term (Schwartz, 1977). Even if individuals consider particular values as central in their life, these values need to be in the focus of their attention in order to become activated (Verplanken and Holland, 2002). Thus, biospheric-altruistic values need to be made more salient to encourage people to act in line with this value orientation (Groot and Steg, 2007). Previous studies found that biospheric-altruistic values can be activated by providing people with visual pro-environmental cues such as nature pictures (Verplanken and Holland, 2002; Hahnel et al., 2014).

Worldviews provide people with general beliefs about reality in a specific domain of life (Stern et al., 1995b). Systems thinking is conceptualized as a worldview reflecting beliefs about the interconnected nature of reality which is assumed to help people to grasp how the consequences of their behavior (Meadows, 2008). This kind of systemic understanding can be activated by drawing people's attention to the interconnected nature of reality, e.g. by asking them to create models or causal diagrams (Hmelo-Silver et al., 2017; Cox et al., 2019) and by asking them to reflect on the consequences of their own behavior (chapter 3).

Beliefs about the existence of environmental problems can be strengthened by providing information about environmental issues in the moment of choice (Schubert, 2017). Extant studies demonstrate that providing consumers with relevant informational videos increases their willingness-to-pay for environmentally-friendly products (Francisco et al., 2015; Lusk, 2018). For example, Klaiman et al. (2016) found that showing participants an infographic or video about recycling enhances their preference for recyclable sandwich containers and willingness to pay for fruit drinks with recyclable packaging respectively.

Social norms have been found to be among the most powerful behavioral antecedents (Schwartz, 1977; Cialdini and Trost, 1998). Empirical studies suggest that providing normative information stimulates people to act in line with their peers (Schultz et al., 2007; Goldstein et al., 2008). Building on these insights, normative information such as information about the behavior or preferences of others appears to be a powerful tool to mobilize action against social and pro-environmental problems (Parks et al., 2001; Cialdini et al., 2006; Hafner et al., 2019). For example, Nolan et al. (2008) found that normative information was more effective in changing households' conservation behavior compared to other types of information.

However, the effectiveness of the presented green nudges seems to depend on individual differences in cognitive styles. This is due to the effect of the decision-making context might differ between people who usually engage in more deliberate slow thinking rather than in intuitive fast thinking (Smith and Levin, 1996; Carnevale et al., 2011). People's cognitive style is conceptualized as a personality trait and can be assessed by the "Need for cognition" (NFC) measure developed by Cacioppo and Petty (1982). People scoring high on the NFC measure base their decision on cognitive deliberation and rational arguments, whereas people low in NFC rather base their decisions on their intuition and emotions (Cacioppo et al., 1996). However, studies found contradictory results regarding the moderating effect of NFC on the susceptibility of decision-makers to variations in the choice context (Mandel and Kapler, 2018). Hence, this study aims to evaluate the effects of the presented green nudges on consumer WTP for bio-based plastic packaging while taking individual differences in NFC into account.

4.3 Methods

This study draws upon an online survey with a discrete choice experiment (DCE) and a between-subject design approach to assess the effectiveness of green nudges to increase consumer WTP for bio-based plastic packaging. The survey consists of three sections. The first section includes questions about socio-demographics, consumption habits, and food values. In the second section, participants are randomly assigned to one of seven treatment groups. The treatment groups represent different green nudges followed by the DCE questions. The last section consists of the German need for cognition measure (Bless et al., 1994) based on Cacioppo and Petty (1982). Finally, we ask for respondents' beliefs about the innovativeness, healthiness, naturalness, environmental-friendliness, and affordability of cherry tomatoes with the bio-based label. The target population is composed of German consumers responsible for food purchases in their households and who purchased the product of interest within the last three months. The following sub-sections describe the procedures that we followed to design the DCE survey and the treatments.

4.3.1 Online Choice Experiment

During the online DCE survey, respondents were asked to make discrete choices between two options of packaged cherry tomatoes and a no purchase option. Vegetables are in general viewed as a promising application field for bio-based plastic packaging (Peelman et al., 2013) as they are short shelf life products and have low requirements regarding their packaging functionalities (e.g. water and oxygen barriers). Most importantly, tomatoes are chosen as the product of interest for this study as they are the most frequently purchased fresh vegetable among Germans (Statista, 2018a).

The attributes and attribute levels of the product in question were selected based on relevant literature (Koutsimanis et al., 2012; Klaiman et al., 2016) and a focus group discussion conducted prior to the experiment. The four attributes are bio-based plastic packaging label, disposal method, organic label, and price, as shown in Table 4.1.

Table 4.1. Attributes and levels.

Attributes	Levels
Bio-based plastic packaging label	Present/Absent
Packaging disposal	Recycling label, Compostable label, No label
Organic label	Present/Absent
Price	0.99 €, 1.89 €, 2.79 €, 3.69 €

Since bio-based plastic is not distinguishable from conventional plastic, a label was designed to indicate that the plastic packaging is bio-based. In addition, prior studies indicate that consumers are willing to pay a price premium for biodegradable containers (Yue et al., 2010) or recyclable packaging of fruit drinks (Klaiman et al., 2016). Hence, we also include labels indicating that the packaging is industrially compostable or mechanically recyclable[5]. Further, the organic label is also used, as its presence has been found to be an important factor in the purchase decision of fresh produce (Kim et al., 2018; Baum and Weigelt, 2019). Finally, the price levels were selected to reflect actual market price ranges, which were also validated by the results of a pre-test.

Given the attributes and attribute levels selected, a full factorial design would require $(4^1 \times 2^2 \times 3^1)^2 = 2304$ different choice questions. Following Street et al. (2005), the full factorial design is reduced to 24 with a D-efficiency of 97.60 (main effects only). To further reduce the number of choice questions shown to respondents during the survey, the 24 choice questions are split in three blocks of 8 choice questions each. To avoid ordering effects, the order of the choice tasks is randomized. An example of a choice set is presented in Figure 4.1.

[5] Participants are provided with more detailed information about the labels (see Appendix J)

Which of the following alternatives would you choose?

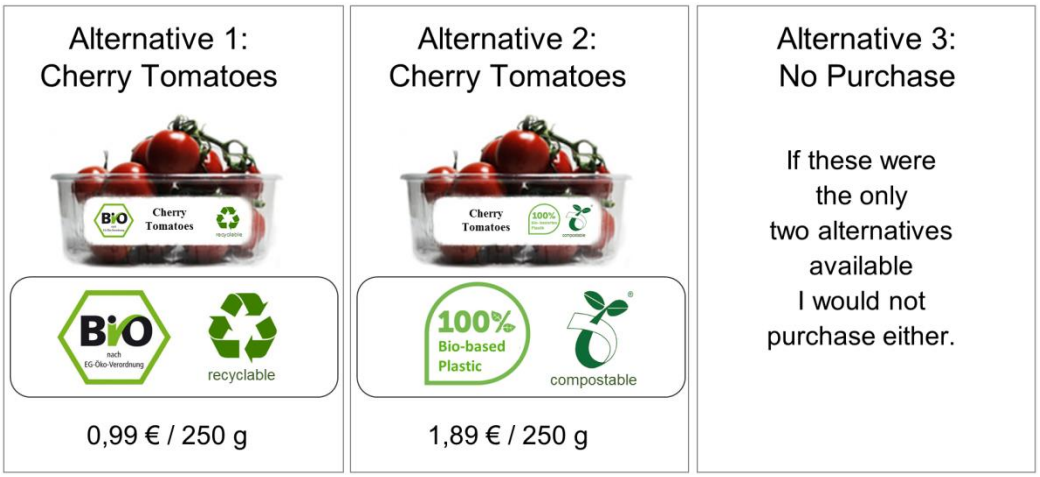

Figure 4.1. Example choice question.

During the survey, participants are faced with 8 choice questions, each represented by two cherry tomatoes products and the opt-out option (no-purchase). Prior to the choice questions, respondents are also provided with an instruction about the DCE and asked to read a cheap talk script[6] (see Appendix I). In order to force respondents to carefully read both the instructions and the cheap talk, they were not able to continue with the questionnaire until 1 minute had elapsed.

4.3.2 Between-Subject Treatments

Before answering the DCE questions, participants are randomly assigned to one of seven treatment groups. These treatment groups are designed to explore if and how consumer WTP for bio-based plastic packaging increases through green nudges aimed to activate pro-environmental values, beliefs, and social norms. The treatments are named as follows: *Control, Label Information, Control for Value, Value Activation, Systems Thinking Activation, Belief Activation* and *Norm Activation*. Table 4.2 summarizes the treatments, while Appendix J reports the specific information respondents received in each treatment[7].

[6] This approach is based on the idea that explaining hypothetical bias and reminding of potential budget constraints motivate respondents to decide as if they were in a real buying situation (Cummings and Taylor (1999); van Loo et al. (2011).

[7] To encourage participants to read the provided information, specific time frames were determined before the button to advance appeared. Additionally, true-or-false questions were used to screen out inattentive participants.

Table 4.2. Overview Treatments.

Treatments	Name	Description
Control	CTRL	DCE questions
Label Information	BASIC	Label information + DCE questions
Control for Value	BASIC_V	Label information + 10 neutral pictures + DCE questions
Value Activation	VALUE	Label information + 10 nature pictures + DCE questions
Worldview Activation	WVIEW	Label information + Video + Reflection questions + DCE questions
Belief Activation	BELIEF	Label information + Video + Text summary + DCE questions
Norm Activation	NORM	Label information + Normative information + DCE questions

In the *Control* (hereafter CTRL), participants are asked to respond only to the DCE questions, while in the other treatments, participants are faced with information or asked to undertake diverse tasks prior to the DCE questions. To illustrate, in the *Label Information* treatment (hereafter BASIC), prior to the DCE questions, participants receive information about the meaning of the bio-based, organic, recycling, and compostable labels. As the majority of German consumers are not familiar with bio-based labels (Rumm, 2016), we assume that an information about the label increases preferences for bio-based plastic packaging. The same set of label information is also used in the remaining treatments prior to the introduction of the other tasks. This allows us to capture the net effects of the remaining treatments. For instance, in the pro-environmental *Value Activation* treatment (hereafter VALUE), prior to the DCE questions and information about the labels, participants are provided with ten pictures of nature landscapes from the databases of the Nencki Affective Picture System (Marchewka et al., 2014) and are asked to rate their attractiveness to increase attention (Hahnel et al., 2014). The nature associations of pictures in the VALUE treatment are assumed to prime consumers' pro-environmental values and preferences for bio-based plastic packaging. In order to make sure that the effect of the pictures can be ascribed to the pro-environmental content as opposed to the positive valence, an additional control group specifically for VALUE is introduced (hereafter BASIC_V)[8]. In the *Systemic Worldview Activation* treatment (hereafter WVIEW), participants are provided with a video about the concept of the bio-economy made by the Federal Ministry for Education and Research (BMBF). In

[8] In CTRL_V, participants receive ten pictures with objects such as buildings, toys or cars from the Nencki database. A pre-study (N = 63) indicates that the pictures in VALUE are significantly stronger associated with nature than in CTRL_V, but do not significantly differ in terms of their perceived valence.

addition, they are asked to list the environmental consequences of fossil-based and bio-based plastics. The cognitive deliberation about the relationship between the consumers' own purchasing decisions and environmental consequences is assumed to activate respondents' systemic worldview (chapter 3). In the pro-environmental *Belief Activation* treatment (hereafter BELIEF), participants are also provided with the same Video as in WVIEW. In addition, participants receive a short text about the fossil-based and bio-based plastic production. The information is hypothesized to increase participants' awareness of pro-environmental benefits of bio-based plastic. Finally, in the *social norm activation* treatment (hereafter NORM), participants receive the information that the majority of Germans (in fact 77.5 %) support bio-based plastic[9]. This information is assumed to activate participants' injunctive social norms[10] so that they want to conform with most Germans and feel an increased personal obligation to purchase bio-based packaged products.

4.3.3 Data Analysis

The DCE data was analyzed using discrete choice models. Following previous studies on consumer preferences for sustainable labels (Caputo et al., 2013; van Loo et al., 2015), this study uses a random parameter logit model with an error component (RPL-EC). As suggested by (Scarpa et al., 2005), the utilities of the purchase options might correlate between each other but not with the no-purchase option. The RPL-EC model allows to account for this heteroscedasticity by adding a normally distributed random error component with zero mean in the estimation which is only associated with both the purchasing alternatives. To test for treatment effects, we followed two modeling approaches. The first approach employs a segmented sample approach to estimate a RPL-EC model in preference space[11]. The indirect utility that individual *n* derives from alternative *j* at choice occasion *t* can be expressed with the following functional form:

$$U_{njt} = ASC + \alpha PRICE_{njt} + \beta_{1n} BIOB_{njt} + \beta_{2n} ORG_{njt} + \beta_{3n} COMP_{njt} + \beta_{4n} RECY_{njt} + 1_j(\eta_{nt}) + \varepsilon_{njt} \quad (2)$$

[9] This statement is based on a study conducted by the technical university of Munich in 2016 (Rumm, 2016)

[10] Injunctive social norms are based on social approval of a certain activity as defined by Cialdini et al. (1990).

[11] Models in preference space specify the distribution of coefficients in the utility function to derive the distribution of WTP as defined by Train and Weeks (2005).

where ASC is an alternative-specific constant representing the no-buy option; $PRICE_{njt}$ represents a continuous variable with the price levels for a package of 250 grams of cherry tomatoes; $BIOB_{njt}$ and ORG_{njt} are dummy variables taking the value 1 if the product carries the corresponding label, and 0 otherwise (compare Fig. 1). $COMP_{njt}$ and $RECY_{njt}$ are dummy variables taking the value 1 if the packaging is compostable or recyclable respectively; $1_j(\cdot)$ is an indicator function that takes the value of 1 for the two tomatoes product profiles; and η_{nt} is a respondent-specific idiosyncratic error component associated with the experimentally designed product alternative but not with the no-buy alternative; and ε_{njt} represents the random error term which follows a Type I Extreme Value distribution. In the model, the price coefficient (α) was assumed to be invariant in the population. On the other hand, the coefficients of the other attributes (β_n) were considered to be random following a normal distribution. To compare differences between marginal WTP estimates across treatments, we performed the combinational test suggested by Poe et al. (2005). The test was based on a distribution of 1,000 WTP estimates[12] for each attribute across treatments and was generated using the parametric bootstrapping method suggested by Krinsky and Robb (1986).

To assess the robustness of the results, the second approach uses a pooled data approach and relies on the use of RPL-EC models estimated in WTP-Space. Models specified in WTP space relax the assumption of a fixed price coefficient (Scarpa et al., 2008) and have the advantage of directly estimating marginal WTP values. As the derived estimates are already the WTP values, this approach offers a practicable comparison of the results across treatments by specifying an extended utility function and by using a pooled data approach (De-Magistris et al., 2013; Caputo et al., 2016; Kim et al., 2018). The extended utility function includes a set of dummy variables identifying specific treatments and the data pooling was executed based on a comparison across treatments: CTRL vs. BASIC, CTRL vs. VALUE, CTRL vs. WVIEW, CTRL vs. BELIEF, CTRL vs. NORM, and BASIC_V vs. VALUE, BASIC vs. WVIEW, BASIC vs. BELIEF, BASIC vs. NORM. Hence, a total of nine models were estimated, one for each treatment comparison.

[12] WTP estimates can be derived by taking the negative ratio of each attribute coefficient, β, and the price coefficient, α.

In each model, the extended utility function in WTP space was specified as follows:

$$U_{njt} = \theta_n[(-PRICE_{njt} + \omega_2 BIOB_{njt} + \omega_3 ORG_{njt} + \theta\omega_4 COMP_{njt} + \omega_5 RECY_{njt} + ASC) + \delta_1(BIOB_{njt}\, x\, TREAT) + \delta_2(ORG_{njt}\, x\, TREAT) + \delta_3(COMP_{njt}\, x\, TREAT) + \delta_4(RECY_{njt} x\, TREAT) + 1_j(\eta_{nt})] + \varepsilon_{njt} \quad (3)$$

where θ_n is a random positive scalar representing the price/scale parameter; $PRICE_{njt}$ is a continuous variable populated with the four price levels in the experimental design; and ω are the marginal WTP estimates for the various attributes; *TREAT* is a dummy variable taking the value 1 for respondents in the given treatment group, and 0 otherwise; and δ_i represent the treatment effects on the experimentally designed attributes. The other elements in (3) are specified as in (2). The significance and sign of δ_i establish if the differences in marginal WTP estimated across treatments are statistically significant and their sign is as expected. In those models, the price coefficient is assumed to be random following a log-normal distribution. All the econometric models were estimated with NLogit 6 (Limdep) using 1,000 Halton Draws.

4.3.4 Data and sample characteristics

Data for this study was collected via an online survey in Germany in May 2019. Participants were recruited by Qualtrics. They were screened to ensure they were over 18 years old, responsible for food purchases in their household, and have purchased cherry tomatoes within the last three months. Respondents were excluded if they did not pass the attention filters, and if they took more than 60 minutes to complete the survey. A total of 1019 respondents completed the survey (CTRL=149, BASIC=146, BASIC_V=146, VALUE=146, WVIEW=135, BELIEF=147, NORM=150). Table 4.3 reports the socio-demographic characteristics of the respondents across different treatment groups.

In terms of gender and age distribution, the overall sample is representative for the German population (Destatis, 2017). Looking at the education level, most respondents completed an apprenticeship which is in line with data of the German population (Destatis, 2018). Similarly, the overall distribution of the monthly household income is representative of the German population (Statista, 2019a). Finally, the results of the chi-square tests suggest that the null hypothesis of

equality between treatment groups cannot be rejected at the 5% significance level for these demographic variables.

Table 4.3. Sample Characteristics in percentages.

Variable	CTRL	BASIC	BASIC_V	VALUE	WVIEW	BELIEF	NORM
Gender							
Female	44.3	52.1	46.6	51.4	54.1	56.5	53.3
Male	55.7	47.9	53.4	48.6	45.9	43.5	46.7
$X^2 = 6.4,\ p = 0.37$							
Age							
18 − 34 years	28.9	28.1	28.1	26.0	20.7	23.1	28.0
35 − 49 years	19.5	22.6	15.8	21.2	28.9	27.9	31.3
50 − 65 years	27.5	31.5	30.1	31.5	25.9	29.3	27.4
Over 65 years	24.2	17.8	26.0	21.2	24.4	19.7	13.3
$X^2 = 24.43, p = 0.14$							
Education							
Secondary School	20.1	20.5	18.5	24.7	10.4	21.1	11.3
High School	12.1	10.3	11.6	10.3	18.5	13.6	17.3
Apprenticeship	44.3	40.4	37.0	37.0	39.3	36.1	47.3
University	23.5	28.1	30.8	26.7	31.1	27.2	23.3
$X^2 = 53.50, p = 0.27$							
Household monthly income							
Up to € 1,700	31.5	25.3	30.1	22.6	25.9	24.5	29.3
€ 1,701–3,600	38.9	41.1	38.4	35.6	42.2	38.8	42.7
Over € 3,601	29.5	33.6	31.5	41.8	31.9	36.7	28.0
$X^2 = 10.72, p = 0.55$							
No. of Observations	149	146	146	146	135	147	150

The analysis of the consumption habits reveals a purchasing frequency of cherry tomatoes of 1-2 times per week (42.0%), every two weeks (29.7%), or once a month (16.5%). Only a few respondents purchase cherry tomatoes more than two times per week (10.9%). Moreover, they usually buy 250g (48.2%) or 500g (47.2%) of cherry tomatoes in discounters (40.5%) or supermarkets (51.3%). The majority of the respondents usually purchases cherry tomatoes with plastic packaging (77.2 %), whereas only few respondents purchase cherry tomatoes with paper

packaging (11.7%) or unpackaged cherry tomatoes (11.1%). Descriptive results for the consumption habits by treatment group are reported in Appendix K.

4.4 Results

4.4.1 Label beliefs across treatments

After answering the DCE questions, participants were asked to report their beliefs about the innovativeness, healthiness, naturalness, environmental-friendliness, and affordability of cherry tomatoes with the bio-based label (Table 4.4).

Table 4.4. Beliefs about the bio-based label across Treatment Groups.

	CTRL	BASIC	BASIC_V	VALUE	WVIEW	BELIEF	NORM
Innovativeness	3.76	3.95	3.76	3.78	4.04	**4.08**	4.06
$X^2 = 34.77$, $p = 0.07$	[.86]	[.82]	[.84]	[.82]	[.83]	[.79]	[.79]
Healthiness	3.43	3.42	3.38	3.26	3.45	**3.59**	3.41
$X^2 = 33.64$, $p = 0.09$	[.74]	[.73]	[.74]	[.76]	[.69]	[.76]	[.79]
Naturalness	3.36	3.51	3.55	3.36	3.67	**3.77**	3.60
$X^2 = 35.89$, $p = 0.06$	[.89]	[.82]	[.89]	[.94]	[.79]	[.85]	[.87]
Environmentally-friendliness	3.87	4.03	3.93	3.90	4.15	**4.20**	4.12
$X^2 = 33.81$, $p = 0.09$	[.87]	[.77]	[.88]	[.79]	[.70]	[.77]	[.82]
Affordability	**2.91**	2.85	2.78	2.78	2.71	2.88	2.60
$X^2 = 43.40$, $p = 0.01$	[.82]	[.82]	[.74]	[.81]	[.87]	[.94]	[.88]

Note: Numbers in parentheses are standard deviations. Numbers in bold are highest values for each label belief. Beliefs are measured on a scale from 1 = 'do not agree at all' to 5 = 'absolutely agree'.

The results of the chi-square tests suggest that the differences in respondents' beliefs between treatment groups are statistically significant at the 10% level. Comparing the results descriptively, we found the highest ratings for the innovativeness, healthiness, naturalness, and environmental-friendliness of cherry tomatoes with the bio-based label in BELIEF. Moreover, respondents in CTRL had the highest ratings of the affordability of cherry tomatoes with bio-based packaging.

4.4.2 Results of the choice experiment across treatments

Table 4.5 reports the coefficient estimates from the RPL-EC model in preference space across treatments.

Table 4.5. Estimates of RPL-EC Model across treatments.

	CTRL	BASIC	BASIC_V	VALUE	WVIEW	BELIEF	NORM
BIO-BASED							
Mean	0.83***	0.90***	0.77***	0.68***	1.50***	1.35***	1.78***
	(0.19)	(0.17)	(0.18)	(0.16)	(0.24)	(0.18)	(0.25)
St. dev.	1.49***	1.22***	1.23***	1.00***	1.33***	1.10***	1.84***
	(0.22)	(0.20)	(0.23)	(0.20)	(0.27)	(0.20)	(0.26)
ORGANIC							
Mean	1.33***	1.40***	1.51***	1.09***	1.58***	1.44***	2.03***
	(0.21)	(0.21)	(0.23)	(0.20)	(0.26)	(0.19)	(0.28)
St. dev.	1.87***	1.88***	2.04***	1.83***	2.22***	1.41***	2.37***
	(0.29)	(0.30)	(0.32)	(0.40)	(0.33)	(0.20)	(0.28)
COMPOSTABLE							
Mean	1.24***	0.92***	0.88***	0.81***	1.71***	1.12***	1.51***
	(0.23)	(0.20)	(0.21)	(0.21)	(0.29)	(0.21)	(0.28)
St. dev.	1.55***	1.49***	1.11***	1.47***	1.82***	1.38***	2.22***
	(0.31)	(0.25)	(0.33)	(0.30)	(0.42)	(0.31)	(0.30)
RECYCLABLE							
Mean	1.10***	0.86***	0.73***	0.76***	1.52***	1.21***	1.24***
	(0.22)	(0.19)	(0.22)	(0.19)	(0.27)	(0.19)	(0.22)
St. dev.	1.36***	1.04***	1.30**	1.09***	1.53***	0.92***	1.10***
	(0.29)	(0.26)	(0.52)	(0.24)	(0.34)	(0.21)	(0.25)
PRICE							
Fixed coeff.	-2.19***	-1.66***	-2.40***	-1.66***	-2.42***	-1.61***	-2.27***
	(0.14)	(0.10)	(0.15)	(0.11)	(0.18)	(0.10)	(0.15)
NO-BUY							
Fixed coeff.	-3.75***	-2.85***	-3.91***	-3.06***	-3.44***	-2.41***	-2.96***
	(0.37)	(0.30)	(0.34)	(0.29)	(0.39)	(0.30)	(0.36)
EC							
St. dev.	2.51***	1.89***	1.70***	1.61***	2.13***	1.95***	2.46***
	(0.36)	(0.50)	(0.54)	(0.25)	(0.36)	(0.30)	(0.47)
Summary statistics							
N	1192	1168	1168	1168	1080	1176	1200
Log-likelihood	-770.57	-838.60	-736.05	-845.96	-690.65	-823.23	-780.82
AIC/N	1.33	1.47	1.30	1.49	1.32	1.44	1.34

Note: Numbers in parentheses are standard errors. Single, double and triple asterisk (*, **, ***) indicate statistical significance at the 10%, 5%, and 1 % level, respectively.

The coefficient of the alternative specific constant (ASC) is significant and negative across all treatments, suggesting that respondents gain a higher utility from choosing cherry tomatoes than from choosing the no-buy option. As expected, the price coefficient is also significant and of negative sign. The coefficients of the bio-based, organic, recyclable, and compostable label are statistically significant and positive, indicating that participants gain a higher utility from cherry tomatoes labeled with the given attributes than from the unlabeled ones. The significant standard deviations of the random parameters reveal that preferences for the bio-based, organic, recyclable, and compostable label are heterogenous. The standard deviation of the EC is also significant across all treatment groups, indicating that the variance in utility is larger for purchase than for the no-purchase options.

Given the differences in scales embedded in the models estimated for each treatment, the interpretation of coefficients is discouraged (Hensher and Greene, 2003). Hence, we discuss the results from the various treatments in the context of the marginal WTP estimates.

Figure 4.2 reports the marginal WTPs across the treatment groups. Marginal WTP estimates in CTRL indicate that, on average, consumers are willing to pay a price premium for bio-based plastic packaging as well as for the organic, compostable and recyclable label. Most notably, results also indicate that the marginal WTP estimates for all product labels seem to differ in magnitude across the CTRL and the other treatment groups.

In order to test the differences between the marginal WTP estimates across treatment groups, we applied the combinational method of Poe, Giraud, and Loomis (2005), which was performed using 1000 bootstrapped marginal WTP estimates obtained from the Krinsky-Robb (1986) procedure. The results of the hypothesis tests are presented in Table 4.6.

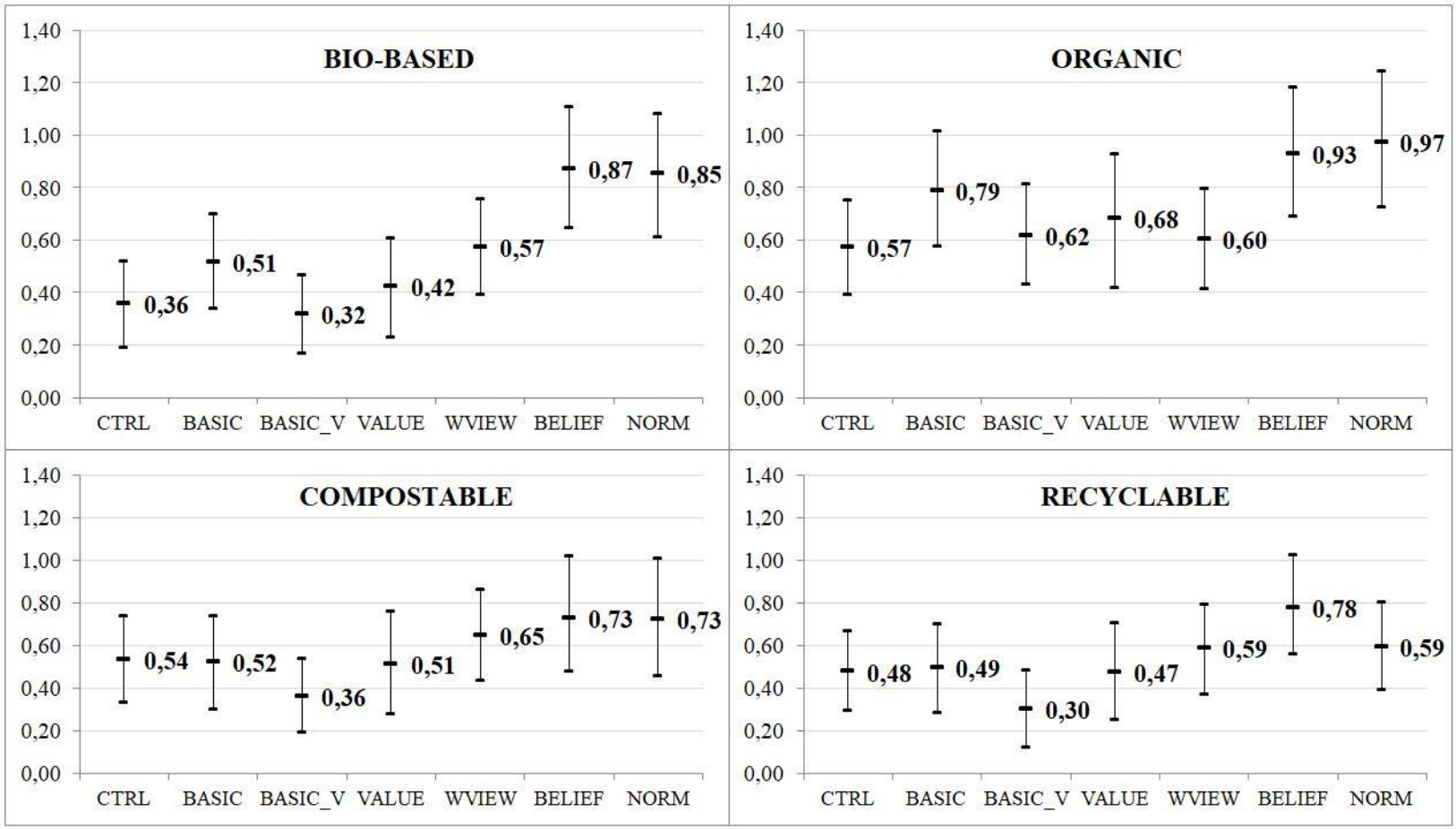

Figure 4.2. Marginal WTP means and 95 % confidence intervals by treatments.

Table 4.6. Marginal WTP Values (€/250 grams) and treatment effects.

Treatment effects	BIOBA	ORG	COMP	RECY
$WTP_{BASIC} - WTP_{CTRL}$	[0.514 - 0.356]	[0.786 - 0.574]*	[0.522 - 0.536]	[0.494 - 0.477]
p-value	0.104	0.076	0.537	0.455
$WTP_{VALUE} - WTP_{CTRL}$	[0.422 - 0.356]	[0.683 - 0.574]	[0.512 - 0.536]	[0.472 - 0.477]
p-value	0.299	0.243	0.562	0.516
$WTP_{WVIEW} - WTP_{CTRL}$	[0.573 - 0.356]**	[0.603 - 0.574]	[0.649 - 0.536]	[0.578 - 0.477]
p-value	0.041	0.418	0.225	0.237
$WTP_{BELIEF} - WTP_{CTRL}$	[0.871 - 0.356] ***	[0.930 - 0.574] **	[0.730 - 0.536]	[0.779 - 0.477] **
p-value	0.000	0.010	0.125	0.024
$WTP_{NORM} - WTP_{CTRL}$	[0.853 - 0.356] ***	[0.971 - 0.574] **	[0.725 - 0.536]	[0.594 - 0.477]
p-value	0.000	0.006	0.138	0.206
$WTP_{VALUE} - WTP_{BASIC\_V}$	[0.422 - 0.319]	[0.683 - 0.618]	[0.512 - 0.362]	[0.472 - 0.299]
p-value	0.191	0.340	0.165	0.125
$WTP_{WVIEW} - WTP_{BASIC}$	[0.573 - 0.514]	[0.603 - 0.786]	[0.649 - 0.522]	[0.578 - 0.494]
p-value	0.326	0.884	0.210	0.282
$WTP_{BELIEF} - WTP_{BASIC}$	[0.871 - 0.514] ***	[0.930 - 0.786]	[0.730 - 0.522]	[0.779 - 0.494] **
p-value	0.008	0.198	0.118	0.035
$WTP_{NORM} - WTP_{BASIC}$	[0.853 - 0.514] **	[0.971 - 0.786]	[0.725 - 0.522]	[0.594 - 0.494]
p-value	0.013	0.147	0.126	0.250

Note: Single, double and triple asterisk (*, **, ***) indicate statistical significance at the 10%, 5%, and 1 % level, respectively. Numbers in parentheses are marginal WTP means.

This table is quite revealing in several ways. First, comparing WTP estimates of BELIEF and CTRL, we find significant differences for the bio-based label. By comparing BELIEF with BASIC, the difference in WTP estimates of the bio-based label remains significant, thereby suggesting that the effect is explained by the additional video and text information. Second, we also find a significant treatment effect of NORM on WTP for the bio-based label compared to CTRL. Similarly, as in BELIEF, the effect on WTP is robust for the bio-based label when comparing NORM with BASIC. Third, we find a significant treatment effect of WVIEW on WTP for the bio-based label when compared to CTRL. However, when comparing WTP values of WVIEW with BASIC, there is no statistically significant difference. Fourth, looking at VALUE, we find no statistically significant differences in WTP estimates compared to both CTRL and BASIC_V. Finally, results indicate that although WTP values for the bio-based label are higher in BASIC compared to CTRL, the differences are not statistically significant.

The results of the Poe (2005) tests also reveal that the magnitude of WTP values of the other labels also changes across treatments. To illustrate, comparing CTRL and BASIC, the difference in WTP for the organic label is statistically significant. Comparing BELIEF and CTRL, we find significant differences for the organic and recyclable label. Only the effect on WTP for the recyclable label remains significant by comparing BELIEF and BASIC. For NORM, we find treatment effects on WTP for the organic label compared to CTRL. However, similarly as in BELIEF, the effect on WTP is only robust for the bio-based and not for the organic label when comparing NORM with BASIC.

Table 4.7 reports the estimated parameters from the pooled sample and the corresponding p-values of the dummy treatment variables as reported in equation (3). In the first step, the treatment groups are pooled with CTRL (upper part of Table 4.7) and, in the second step, they are pooled with BASIC to estimate the net effects of the treatments (lower part of Table 4.7).

Table 4.7. Robustness Test in WTP Space (€/ 250 g).

	BASIC	VALUE	WVIEW	BELIEF	NORM
BIOBA x $TREAT_i$ [a]	**0.281** (0.207)	**0.118** (0.204)	**0.365** (0.226)	**0.680*** ** (0.219)	**0.525**** (0.231)
p-value	0.175	0.561	0.107	0.000	0.023
ORG x $TREAT_i$ [a]	**0.372** (0.240)	**0.118** (0.251)	**- 0.129** (0.271)	**0.319** (0.221)	**0.278** (0.271)
p-value	0.122	0.637	0.635	0.148	0.304
COMP x $TREAT_i$ [a]	**- 0.046** (0.248)	**0.050** (0.244)	**0.265** (0.267)	**0.102** (0.241)	**- 0.046** (0.276)
p-value	0.854	0.839	0.321	0.672	0.869
RECY x $TREAT_i$ [a]	**- 0.191** (0.229)	**- 0.072** (0.241)	**0.237** (0.273)	**0.137** (0.241)	**- 0.331** (0.247)
p-value	0.403	0.765	0.386	0.569	0.180
BIOBA x $TREAT_i$ [b]	-	**0.152** (0.201) [c]	**0.038** (0.196)	**0.357*** (0.190)	0**.177** (0.080)
p-value	-	0.450	0.845	0.06	0.400
ORG x $TREAT_i$ [b]	-	**0.070** (0.245) [c]	**- 0.488*** (0.254)	**- 0.063** (0.210)	**- 0.186** (0.247)
p-value	-	0.776	0.055	0.765	0.452
COMP x $TREAT_i$ [b]	-	**0.311** (0.239) [c]	**0.260** (0.264)	**0.143** (0.223)	**- 0.051** (0.245)
p-value	-	0.193	0.326	0.523	0.837
RECY x $TREAT_i$ [b]	-	**0.250** (0.244) [c]	**0.387** (0.244)	**0.302** (0.209)	**- 0.101** (0.232)
p-value	-	0.304	0.113	0.148	0.664

Note: In $TREAT_i$, i = BASIC, VALUE, WVIEW, BELIEF, NORM; a = pooled with CTRL; b = pooled with BASIC; c = pooled with BASIC_V. Single, double and triple asterisk (*, **, ***) indicate statistical significance at the 10%, 5%, and 1 % level, respectively.

The results of the robustness test are in line with the findings from the Poe et al. (2005) test for bio-based plastic packaging in seven out of nine treatment comparisons. In contrast to previous findings, no statistically significant effect was found for NORM compared to BASIC as well as for WVIEW compared to CTRL. Given both the results of the Poe test and the robustness test, we could only find empirical support for the effectiveness of the BELIEF treatment.

4.4.3 Interaction between treatments and consumer cognitive styles

To account for consumer differences in cognitive style, we additionally perform a sub-sample analysis by estimating separate models in WTP-Space for two groups based on the median of the "Need for cognition" (NFC) measure: respondents low versus high in NFC. Conditional parameters of WTP (or individual-level WTPs) are used following the procedures described in Train (2009) and Hensher et al. (2015). Figure 4.3 presents the individual-level marginal WTP estimates for each subsample segmented by treatment and NFC level (high versus low).

The figure shows that the magnitude of WTP values strongly differs across treatment groups and NFC levels. To illustrate, for the bio-based label, WTP values in CTRL, BASIC, and VALUE are higher for respondents low in NFC than for those high in NFC; whereas the opposite is true for BASIC_V, WVIEW, BELIEF and NORM. For the organic label, respondents high in NFC are willing to pay more compared to respondents low in NFC across all treatment groups, except for VALUE where WTP values are similar. Similarly, respondents high in NFC are willing to pay more than respondents low in NFC for the compostable and for the recyclable label across all treatments, except in CTRL and BASIC_V, where WTP values are higher or similar for respondents low in NFC.

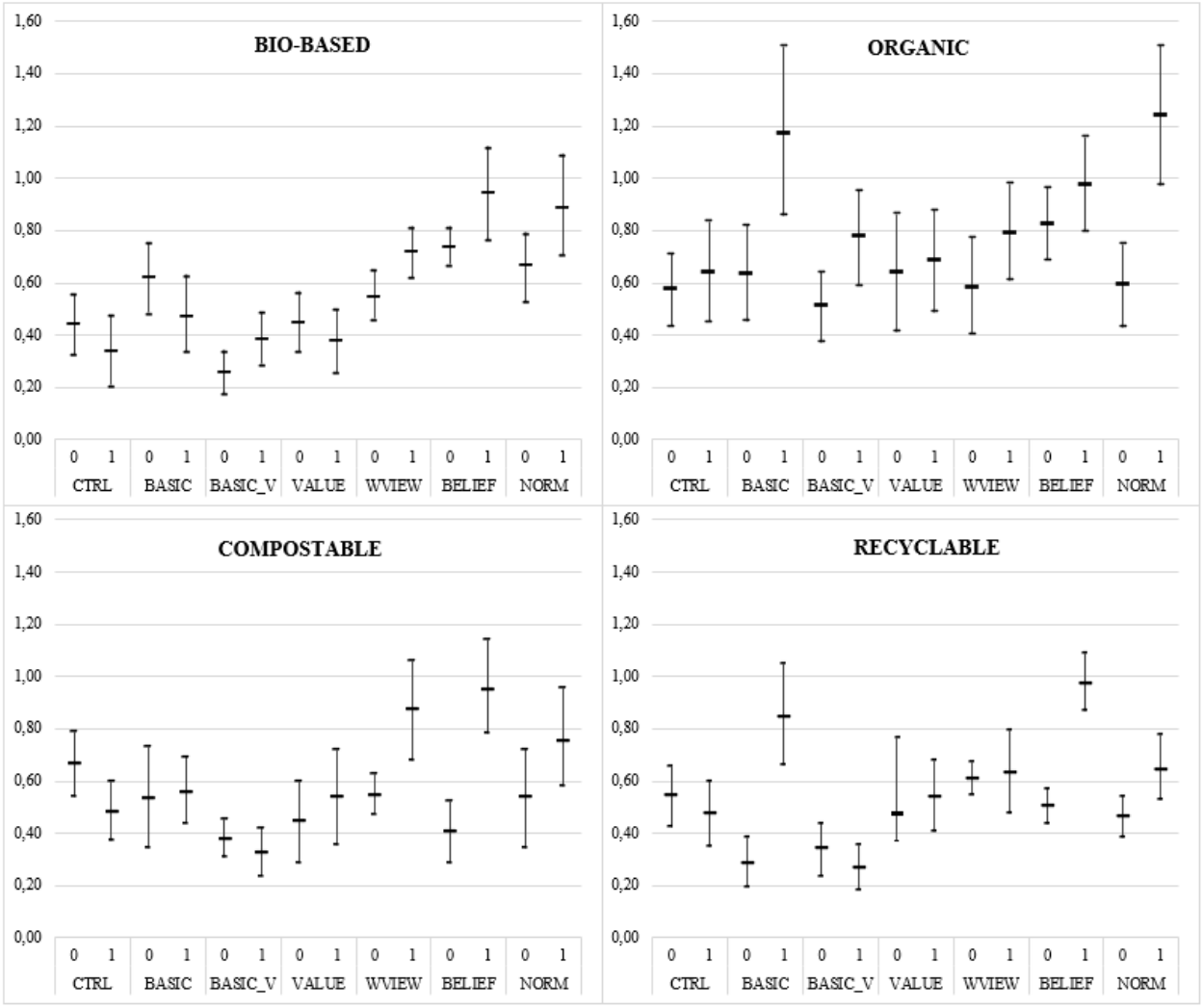

Figure 4.3. Marginal WTP means and 95 % confidence intervals by treatments/ NFC level.

Note: 0 = low NFC, 1 = high NFC.

In order to evaluate the treatment effects, we apply the nonparametric Mann-Whitney U test to compare the means of individual WTP values[13]. Table 4.8 reports the statistical significance of differences between WTP values of BASIC and the VALUE, WVIEW, BELIEF and NORM treatment by taking consumers NFC level into account.

[13] The nonparametric Mann-Whitney U test was applied as the individual WTP values were not normally distributed.

Table 4.8. Treatment effects on individual WTP values (€/250 grams) by NFC level.

Treatment effects	BIOBA	ORG	COMP	RECY
LOW NFC				
$WTP_{BASIC} - WTP_{CTRL}$	[0.620 – 0.446]*	[0.635 – 0.576]	[0.536 – 0.669]**	[0.289 – 0.546]***
p-value	0.049	0.742	0.039	0.002
$WTP_{VALUE} - WTP_{BASIC\_V}$	[0.450 – 0.257]**	[0.642 – 0.515]	[0.446 – 0.382]	[0.371 – 0.344]
p-value	0.005	0.734	0.443	0.877
$WTP_{WVIEW} - WTP_{BASIC}$	[0.552 – 0.620]	[0.582 – 0.635]	[0.546 – 0.536]**	[0.609 – 0.289]***
p-value	0.987	0.353	0.028	0.000
$WTP_{BELIEF} - WTP_{BASIC}$	[0.739 – 0.620] ***	[0.827 – 0.635]*	[0.405 – 0.536]	[0.505 – 0.289]***
p-value	0.004	0.053	0.931	0.000
$WTP_{NORM} - WTP_{BASIC}$	[0.666 – 0.620]	[0.595 – 0.635]	[0.537 – 0.536]	[0.468 – 0.289]***
p-value	0.282	0.970	0.617	0.001
HIGH NFC				
$WTP_{BASIC} - WTP_{CTRL}$	[0.475 – 0.340]	[1.171 – 0.639]**	[0.560 – 0.485]	[0.847 – 0.475]***
p-value	0.354	0.016	0.527	0.004
$WTP_{VALUE} - WTP_{BASIC\_V}$	[0.380 – 0.386]	[0.687 – 0.781]	[0.537 – 0.330]	[0.537 – 0.272]***
p-value	0.723	0.371	0.200	0.002
$WTP_{WVIEW} - WTP_{BASIC}$	[0.722 – 0.475]***	[0.792 – 1.171]*	[0.876 – 0.560]***	[0.636 – 0.847]
p-value	0.002	0.082	0.008	0.202
$WTP_{BELIEF} - WTP_{BASIC}$	[0.944 – 0.475]***	[0.976 – 1.171]	[0.955 – 0.560]***	[0.978 – 0.847]
p-value	0.000	0.540	0.001	0.197
$WTP_{NORM} - WTP_{BASIC}$	[0.885 – 0.475]***	[1.240 – 1.171]	[0.755 – 0.560]	[0.647 – 0.847]
p-value	0.002	0.628	0.181	0.106

Note: Single, double and triple asterisk (*, **, ***) indicate statistical significance at the 10%, 5%, and 1 % level, respectively.

The findings generally provide evidence for an interaction effect between the nature of the green nudge and the cognitive style of consumers. For intuitive decision-makers (low NFC), we find statistically significant treatment effects of BASIC, VALUE and BELIEF on WTP for the bio-based label. For rational decision-makers (high NFC), the WVIEW, BELIEF and NORM treatment are found to have statistically significant effects on WTP for the bio-based label. The magnitude of WTP values of the other labels also changes across treatments and NFC level. For instance, in BASIC, consumers high in NFC are willing to pay significantly more for the organic and recyclable label than in CTRL.

4.5 Discussion

4.5.1 General discussion

This study explores the effects of green nudges on consumer WTP for bio-based plastic packaging by conducting a DCE with seven different treatment groups. The results provide evidence that the individual susceptibility of green nudges seems to depend on consumers' cognitive style in three different ways. First, only intuitive decision-makers seem to be influenced by the bio-based label information (BASIC), indicating that the provided information might need to be more detailed to convince consumers high in NFC. Similarly, nature pictures (VALUE) only seem to affect intuitive decision-makers, but not consumers who base their decision on rational arguments. This result is partly in line with Hahnel et al. (2014), who found that nature pictures generally lower the price sensitivity for electric vehicles. However, in the food context, the effects of nature pictures seem to depend on individual differences such as demographics as shown by Bullock et al. (2017). Second, providing normative information (NORM) only triggers rational decision-makers to increase their WTP for bio-based plastic packaging. However, previous studies indicate that normative information about environmental issues generally mobilizes people to engage in the concordant behavior (Cialdini et al., 2006; Nolan et al., 2008). Further research thus needs to investigate whether rational decision-makers are generally more susceptible to normative information or whether this effect occurs because of the way this study presented the normative information. Moreover, rational decision-makers are also more prone to the strategy to reflect on the consequences of bio-based plastic packaging (WVIEW). This effect might occur because environmental consequences of plastic packaging are rather complex and, thus, more accessible for people who enjoy thinking about complex problems. Third, the BELIEF treatment seems to be effective to increase WTP for bio-based plastic packaging of both people low and high in NFC, indicating that the video and text information about the bio-economy are susceptible for rational and intuitive decision-makers. This finding is in line with prior studies indicating that relevant information triggers WTP for pro-environmental products (Francisco et al., 2015; Klaiman et al., 2016, 2017; Lusk, 2018). One of the reason for this effect might be that the information activates the belief that these products are environmentally friendly. Indeed, our results indicate that respondents in BELIEF rate the bio-based label as more environmentally friendly than respondents in CTRL and BASIC.

Moreover, the magnitude of WTP values of the other labels also changes across treatments and NFC level. For instance, results indicate that label information might only affect rational decision-makers to prefer well-known labels. This is in line with findings from Kaminski and Caputo (2018) suggesting that basic label information has a stronger effect on consumers' WTP for already established sustainability labels such as the organic label than on a novel label certifying labor conditions on dairy farms.

Overall, our findings generally show evidence for an interaction effect between the green nudging strategy and cognitive style of consumers. The results can be explained by the meta-analysis from Phillips et al. (2016) who found that the effect of cognitive styles on decision-making depends on the specific task. Without considering respondents' degree of need for cognition, our results would have indicated that neither the activation of values (VALUE) nor worldview (WVIEW) is an effective strategy to increase WTP for bio-based plastic packaging. Nevertheless, taking NFC into account, our study reveals that the strongest effects are generated when the task matches the characteristics of the thinking style.

4.5.2 Theoretical and practical implications

The results of this study have two important theoretical implications for the behavioral economics and environmental psychology literature. First, this is the first study which compares the effectiveness of green nudges which differ according to the internal motivation that they aim to activate. Our findings indicate that green nudges are generally most effective when they are based on the activation of beliefs and social norms. This is in line with the VBN theory assuming that variables in the end of the chain have stronger impacts on behavior (Stern et al., 1999) - or hypothetical WTP which this research uses as a proxy for behavior. Second, our results provide evidence that the effectiveness of green nudges depends on consumers' cognitive styles. This is in line with the theoretical assumption that behavior is influenced by the interaction of external and internal factors (Guagnano et al., 1995). However, in order to develop a profound theory about the interaction of nudging strategies and cognitive styles, more evidence is still needed.

In addition to these theoretical conclusions, this study has three major practical implications for the food industry and policy-makers. First, our findings show that consumers are willing to pay a price premium for bio-based plastic packaging. According to Van den Oever et al. (2017), this premium covers the additional costs for bio-based plastic packaging compared to the conventional alternative. Hence, the food industry could adopt bio-based plastic packaging

without needing to reduce their usual profit margin. However, it is important that the packaging is labeled accordingly because bio-based and fossil-plastic packaging are not distinguishable by the consumers (European Bioplastics, 2019). Second, policy-makers can make use of the green nudges presented in this paper in order to boost consumer preferences for bio-based plastic packaging. Even though consumers are already exposed to several stimuli when making purchase decisions, we recommend the implementation of situational cues to activate consumers' pro-environmental values, beliefs and norms. For example, pro-environmental product attributes and labels need to be made more salient for the consumer. A product design that integrates nature pictures and flyers could deliver additional information about environmental consequences. Since normative information was found to be very effective, it might be advantageous to join forces with social media influencers to provide pro-environmental opinions and practices. In addition, we believe that the reflection about environmental issues should be considered as part of the education of children and young people. Third, marketers of food companies as well as policymakers need to take the different cognitive styles of consumers into account when developing green nudges to increase demand for pro-environmental products. In the future, either the marketers are recommended to use green nudges which are effective for both intuitive and rational decision-makers or they choose the strategy in line with the specific target group. For example, activating reflection about environmental issues might only be a successful strategy to convince people who base their decisions on their cognitive deliberation.

4.5.3 Limitations

The limitations of our study give rise to some implications for further research. Since our data is collected in Germany considering the case of bio-based plastic packaging for cherry tomatoes, there is further evidence needed to test the effectiveness of the chosen green nudges in other areas. More importantly, since this study only conducts a hypothetical choice experiment, future studies need to validate our results with real market data. Moreover, it is not clear whether providing information about the bio-economy and normative information only shortly activate beliefs and norms or even change them in the long run. Therefore, more research is needed in terms of the durability of the effect. Hence, longitudinal studies need to be conducted to assess consumer WTP over several days or months after the information treatments. In addition, studies are needed to look deeper into the causal effect of cognitive styles on consumer willingness to reflect environmental issues. For example, qualitative

interviews with people low and high in NFC could facilitate the comparison of the ideas generated in the reflection process, and also assess the activation of an ecological worldview. Similarly, future studies also need to consider how prior pro-environmental beliefs affect the success of the green nudges. For example, past studies already showed that people are more susceptible to nature pictures if they have strong pro-environmental values (Hahnel et al., 2014) and that people are more likely to adopt information which conform prior beliefs (McFadden and Lusk, 2015; Vainio et al., 2018). These assumptions could be tested by assessing consumer beliefs before and after the treatments. In general, insights of this study might also be applicable to other choice contexts such as managers' decisions to invest in pro-environmental innovations. Thus, we hope that our findings motivate other researchers to explore the relationship between consumers' cognitive styles and their susceptibility towards nudging strategies.

5 Discussion

This chapter summarizes and discusses the findings of the empirical studies presented in the previous chapters (section 5.1). Moreover, it highlights the scientific and practical contributions of this thesis (section 5.2 and 5.3) as well as presents limitations and directions for further research (section 5.4).

5.1 Summary and general discussion

Global challenges such as the rising food and energy demand of the growing world population and depleting fossil resources are increasingly threatening the balance of the social and natural system (Meadows et al., 2004; Godfray et al., 2010; Augustin et al., 2016). One promising strategy to solve these problems is presented by the bio-economy concept which provides a whole set of novel technologies and products to replace fossil resources with bio-based materials (Lusk, 2004; Boehlje and Bröring, 2011; Zilberman et al., 2013; Golembiewski et al., 2015). However, a successful transition from the current fossil-based to a bio-based economy ultimately depends on value chain actors' motivations to adopt these innovations (Rossi and Hinrichs, 2011; Bröring et al., 2017; Klein et al., 2019). Hence, the present research aims to explore behavioral motivations as drivers for the adoption of bio-economy innovations. In this vein, this thesis focuses on farmers and consumers as these value chain actors are assumed to play a huge role for the success of bio-economy innovations (Hauser et al., 2006; Arts et al., 2011; Rossi and Hinrichs, 2011; Bröring et al., 2017). Thus, this dissertation pursues the following two main objectives:

I. To advance the knowledge of how behavioral motivations drive farmers' and consumers' adoption of bio-economy innovations
II. To empirically test strategies to foster the adoption of bio-economy innovations

In order to achieve these objectives, this thesis conducted three empirical studies which aim to answer six research questions. Figure 5.1 provides an overview of the key findings of these studies.

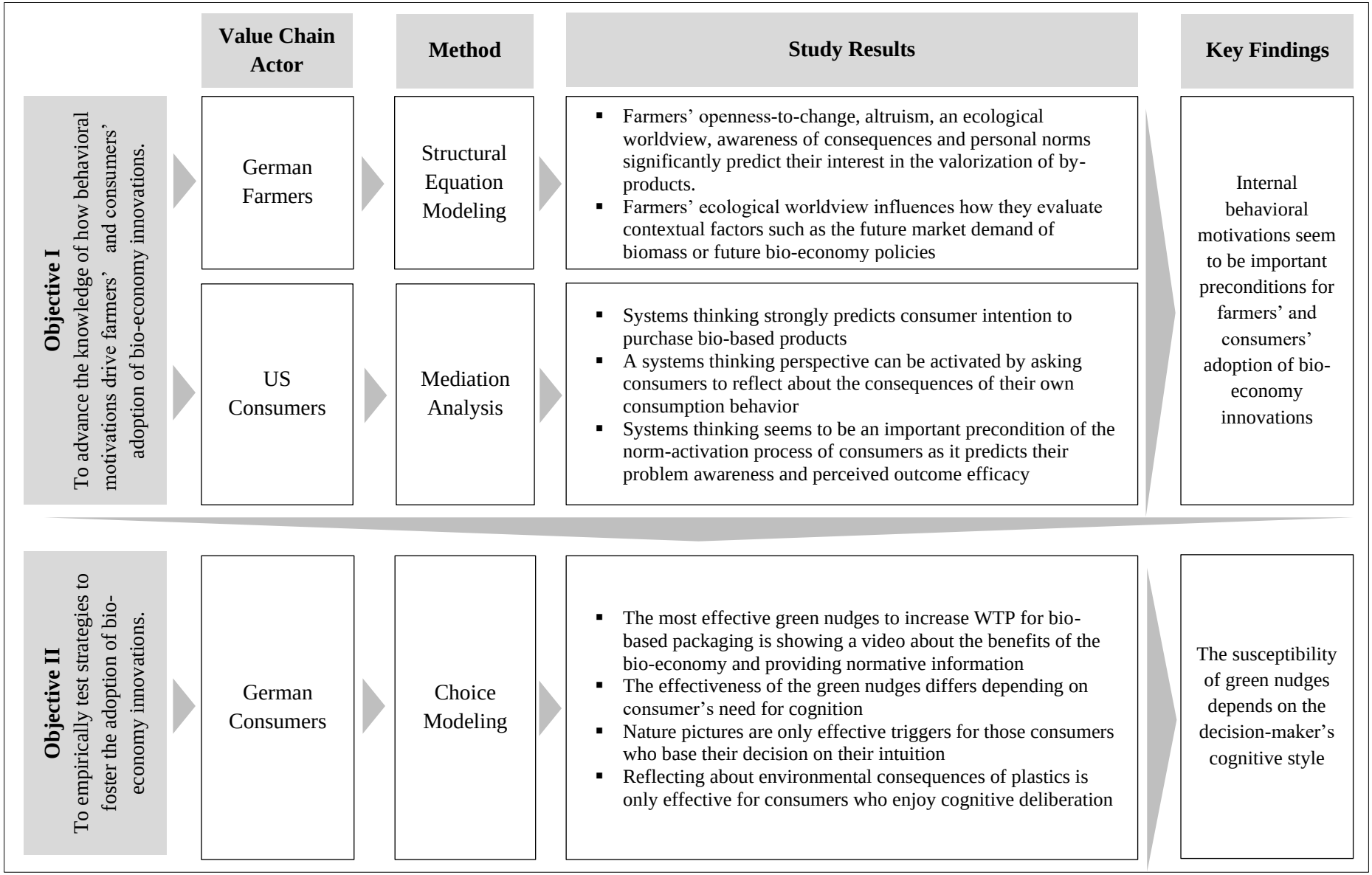

Figure 5.1. Overview of study results and key findings.

Source: Own illustration

The first study in this thesis (chapter 2) assesses the impact of behavioral motivations on farmers' interest in the adoption of bio-economy practices, using the case of the utilization of horticultural by-products as an example. To this aim, data from 96 German fruit and vegetable farmers is collected using a telephone survey and analyzed in a Structural Equation Model. As the adoption of bio-economy innovations can also be understood as a type of pro-environmental behavior, this study addresses the current research gap by exploring if pro-environmental values, an ecological worldview, beliefs and norms affect farmers' interest in bio-economy practices.

RQ 1: Do pro-environmental values, beliefs and norms drive farmers' interest in bio-economy practices?

The results provide evidence that the value-beliefs-norms (VBN) theory (Stern et al., 1999) is a useful framework to understand if farmers are interested in bio-economy practices. Into more detail, farmers' openness-to-change, altruism, an ecological worldview, awareness of consequences and personal norms significantly predict their interest in the valorization of by-products. Combined with prior studies (Seymour et al., 2010; Price and Leviston, 2014), these findings suggest that internal behavioral motivations seem to be important for farmers' decisions to adopt pro-environmental practices.

In addition to these internal motivations, contextual factors such as the market demand of biomass, bio-economy policies and technology developments are also assumed to play an important role in farmers' decisions to adopt bio-economy innovations (Guagnano et al., 1995; Steg and Vlek, 2009). However, the perception of these factors might, in turn, depend on farmers' internal belief system (Guagnano et al., 1995). Hence, this study also explores the interaction between farmers' ecological worldview and their perception of contextual factors.

RQ 2: How does an ecological worldview relate to farmers' perception of contextual factors?

In terms of the general impact of contextual factors, results indicate that those farmers who believe that the market demand of biomass increases in the future are generally more interested in bio-economy innovations. This finding is consistent with the agricultural economics literature (Cary and Wilkinson 1997; Morgan et al. 2015). Nevertheless, results indicate that farmers' interest in valorizing by-products is not affected by their perception of future technological developments in the bio-economy. Moreover, there is no evidence of a relationship between farmers' perceptions of

future bio-economy policies and their interest in bio-economy practices, which conflicts with previous studies (Baumgart-Getz et al. 2012; Rajendran et al. 2016).

In terms of the interaction effects, results indicate that an internal ecological worldview is associated with farmers' perception of the pro-environmental effectiveness of valorizing agricultural by-products as well as of contextual factors (e.g. future market demand of biomass, future bio-economy policies). Despite these positive associations, the direction of causality remains unclear. However, behavioral sciences suggest a causal direction in which internal worldviews shape how people and objects in the external world are perceived and evaluated (Baum and Gross 2017; Otten et al. 2017). Thus, it is assumed that an ecological worldview is potentially relevant of how farmers evaluate the external conditions for the implementation of bio-economy practices. On the other side, the lack of an ecological worldview could represent a potential barrier for the diffusion of bio-economy innovations. Thus, political bio-economy strategies also need to focus on cultivating this type of worldview among farmers (Rossi and Hinrichs, 2011; Schmidt et al., 2012).

The second study in this thesis (chapter 3) draws upon the key finding of the first study indicating that farmers' ecological worldview has a strong direct and indirect effect on their interest in bio-economy practices. However, instead of focusing on farmers, it investigates consumer decisions to adopt bio-economy innovations, using the intention to buy bio-based products as a proxy. Moreover, it explores the role of systems thinking which is also conceptualized as a worldview reflecting cognitive assumptions about the complex and interconnected nature of reality (Randle and Stroink, 2018). In contrast to an ecological worldview, systems thinking not only reflects specific cognitive beliefs about the relationship between humans and the ecological system but also includes domain-general beliefs about the economic and social system (Davis and Stroink, 2015; Randle and Stroink, 2018). Although systems thinking is currently discussed as an important cognitive paradigm for a transition towards a bio-based economy (Lewandowski et al., 2018; Urmetzer et al., 2020), empirical studies are still missing. To this end, an online survey with a between-subject design is employed to collect data from 446 US consumers. This data is analyzed using mediation models in order to explore the direct and indirect impact of systems thinking on consumer intention to purchase bio-based products.

RQ 3: Does systems thinking affect consumer intention to purchase bio-based products?

The results of the second study provide evidence of a positive relationship between systems thinking and purchase intention of bio-based products. This finding is in line with prior research showing that systems thinking affects pro-environmental decision making and behavior (Davis and Stroink, 2015; Lezak and Thibodeau, 2016). However, prior studies indicate that individuals perceive the product attributes differently depending on the product category (e.g, Loebnitz and Bröring, 2015). Thus, it still needs to be assessed whether the impact of systems thinking on purchase intention also varies among product categories, e.g. between bio-based detergents and bio-based cosmetics. More importantly, findings show that a task in which consumers are asked to list the consequences of their own consumption behavior proves to be successful in activating a systems-thinking perspective which, in turn, affects their purchase intention. Whereas current research mainly focuses on using linguistic or visual metaphors, this insight contributes to advance the understanding of how systems thinking can be activated (Thibodeau et al., 2017).

Moreover, the psychological mechanism of how systems thinking affects pro-environmental decision-making is not completely understood yet (Lezak and Thibodeau, 2016; Davis et al., 2017; Ballew et al., 2019). Based on current theories in environmental psychology literature (Davis and Stroink, 2015; Ballew et al., 2019; Klein et al., 2019), the second study also explores how internal values, an ecological worldview, beliefs and norms relate to systems thinking.

RQ 4: How does systems thinking relate to consumers' values, ecological worldview, beliefs and norms?

Findings indicate that the integration of systems thinking could improve existing models from environmental psychology literature in three different ways. First, the relationship between altruism and purchase intention of bio-based products seems to be mediated by systems thinking. This insight is relevant as it provides an explanation for prior findings about a positive association between altruism and pro-environmental behavior (e.g. Steg, 2016; Klein et al., 2019). Second, systems thinking positively influences an ecological worldview which, in turn, affects consumer intention to purchase bio-based products. This result is in line with recent findings from Ballew et al. (2019) who argue that systems thinking is the basis for the development of an ecological worldview. Third, the relationship between systems thinking and intention to buy bio-based products is mediated by consumers' problem awareness, outcome efficacy and personal norms. These insights are relevant as they advance knowledge about the preconditions of the NAM which

is widely used to predict pro-environmental behavior (Schwartz, 1977; Harland et al., 2010; Börger and Hattam, 2017; Ünal et al., 2018). Synthesizing the findings, the model which combines systems thinking with the NAM is an appropriate model to explain consumer intention to purchase bio-based products.

The third study (chapter 4) is dedicated to the second objective of this thesis which is to identify strategies that foster the adoption of bio-economy innovations. As the market share for bio-based plastic packaging still remains small, scholars request policy strategies to increase the consumers' demand for products with this type of packaging (Kainz, 2016; Herbes et al., 2018). The reason is that an increased market demand could facilitate large-scale production systems which lower the costs for companies to switch to bio-based plastic packaging (European Bioplastics, 2019). In this case, behavioral economics suggest to make use of the decision-making context in order to prime people to behave in a predictable way, also known as nudges (Thaler and Sunstein, 2008; Kahneman, 2011). However, it is not known whether nudging strategies also encourage consumers to adopt bio-economy innovations. To this aim, the third study aims to close this research gap. In this vein, it draws upon the findings of the previously presented studies which indicate that internal pro-environmental motivations are relevant for the adoption decision. Thus, this study uses a discrete choice experiment with a between-subject-design to activate consumer values, systemic worldview, beliefs and social norms by providing them with green nudges, i.e. nature pictures, reflection questions, information about the bio-economy and normative information, respectively. By estimating several RPL models, it investigates and compares the effectiveness of these green nudges in terms of triggering consumer willingness to pay for bio-based products, using the case of bio-based plastic packaging as an example.

RQ 5: Which green nudges increase consumer willingness to pay for bio-based plastic packaging?

This is the first empirical study which provides evidence that, on average, consumers state to be willing to pay a premium of 0.36 € for cherry tomatoes with bio-based plastic packaging - even without exposure to additional information. This price premium could cover the additional costs of food companies to swith from conventional plastic packaging to the bio-based alternative (van den Oever et al., 2017). However, it needs to be noted that there exists a gap between consumers' stated preferences and their actual behavior (e.g. Ajzen and Fishbein, 2005; Dirzyte and Rakauskiene,

2016). Scholars discuss different reasons for this inconsistency, e.g. social desirability issues (Milfont, 2009) or practical barriers to perform the actual behavior such as missing product availability (Yamoah and Acquaye, 2019). Hence, the stated WTP values need to be treated with caution. However, they provide first evidence about general preferences of consumers and about the impact of different green nudges on their preferences.

Thus, further findings of this study can be structured into five points. First, providing consumers with video and text information about bio-based plastics increases their WTP for cherry tomatoes with bio-based packaging. Thus, this information might activate or changes the belief that products with bio-based packaging are more environmentally friendly. Indeed, results show that respondents who are provided with the information rate the bio-based label as more environmentally friendly than respondents in the control group. However, it remains unclear whether this belief is only activated for a short-term or whether the belief changed in the long run. This needs to be explored in further longitudinal studies. Second, triggering social norms by highlighting that other consumers prefer bio-based packaging also increases WTP for bio-based packaging. This result confirms previous studies who indicate that normative information mobilizes people to engage in the pro-environmental behavior (Cialdini et al., 2006; Nolan et al., 2008). Third, results indicate that encouraging consumers to reflect on environmental consequences generally does increase their WTP for bio-based plastic packaging. The reason for this effect might be that the reflection activates consumers' systemic worldview as already indicated in the previous study. However, the strategy does not seem to be more effective than providing basic label information. Fourth, nature pictures seem to have no general effect on consumers WTP for bio-based plastic packaging. This result contradicts Hahnel et al. (2014), who found that nature pictures lower price sensitivity for electric vehicles. However, in the food context, the effect of nature pictures depends on individual differences such as demographics (Bullock et al., 2017). This assumption is explored based on the next research question. Finally, there is no evidence that providing consumers with basic information about the bio-based label increases WTP of the given label.

As the effectiveness of these green nudges might differ between people who base their decisions on rational arguments and people who base them on their intuition or emotions (Smith & Levin, 1996; Carnevale et al., 2011), this study also explores the influence of consumers' cognitive style on the previously presented strategies.

RQ 6: How do individual differences in consumers' cognitive styles impact the effectiveness of green nudges?

Findings indeed indicate that consumers' susceptibility to green nudges depends on the state of their individual cognitive style. For instance, the strategy of providing consumers with nature pictures only increases WTP for bio-based packaging of consumers who base their decision on their intuition (low NFC). This could also explain why Bullock & Johnson (2017) found that value-based advertisements only influence some demographic groups. On the other side, the strategies that provide normative information or activate the reflection about environmental consequences of plastics are only effective for consumers who enjoy cognitive deliberation. This finding is also relevant as it might explains why previous studies found contradictory results for the effects of information strategies (e.g. Lusk, 2018; Wuepper et al., 2019). Overall, the findings provide evidence for the interaction effect between the individual and the specific situation on consumer decision-making.

5.2 Scientific contributions

The following sub-sections present the scientific contributions of this thesis from three distinct perspectives. First, the theoretical contributions (section 5.2.1) summarize how the findings of this thesis extend current theories in the innovation adoption, environmental psychology and behavioral economics literature. Second, the methodological contributions (section 5.2.2) depict how this thesis adds to the improvement of current methods to collect and analyze data to assess innovation adoption. Third, the empirical contributions (section 5.2.3) describe the data-based observations of this thesis in the context of the adoption of bio-economy innovations. Table 5.1 presents an overview of the scientific contributions structured by type and its level of contribution.

Table 5.1. Scientific contributions of the thesis.

Type of contribution	Level of contribution		
	Replication	**Extension**	**Innovation**
Theoretical	▪ Application of the VBN theory ▪ Adaptation of green nudges to increase WTP for bio-based packaging based on behavioral economics	▪ Extending the VBN theory by contextual factors ▪ Integrating systems thinking into the NAM	▪ Exploration of the interaction between green nudges and individual cognitive styles
Methodological	▪ Application of a discrete choice experiment with a between-subject design ▪ Adaption of PLS-SEM and mediation analysis	▪ Utilization of interest as the dependent variable ▪ Extending the RPL model by adding an idiosyncratic error component	▪ Development of a treatment to activate systems thinking
Empirical	▪ Validation of the effect of internal motivations and contextual factors in the field of bio-economy	▪ Providing empirical evidence for the role of the VBN-theory and systems thinking in the bio-economy context	▪ Empirical assessment of the effectiveness of green nudges to increase WTP in the case of bio-based plastic packaging

5.2.1 Theoretical contributions

This thesis contributes to current theoretical perspectives in five different ways. First, assuming that the adoption of bio-economy innovations can be understood as a type of pro-environmental behavior, this thesis utilizes the VBN theory (Stern et al., 1999) to understand farmers' adoption decision. In support of the theory, findings show that values, beliefs and norms significantly predict farmers' motivation to gather more information about the practice to valorize agricultural by-products. In the agricultural domain, the VBN theory has already been applied as a framework to explain farmers' intention to adopt practices such as natural resource management (Seymour et al. 2010) or land management (Price and Leviston 2014). However, this research provides first evidence for the adaptability of the VBN theory in the context of bio-economy practices.

Second, the present research draws upon nudging strategies from behavioral economics (Thaler and Sunstein, 2008; e.g. Kahneman, 2011; Schubert, 2017) to investigate if their application is able

to increase consumer WTP for cherry tomatoes with bio-based plastic packaging. The green nudges are chosen to activate pro-environmental values, worldview, beliefs and social norms by providing consumers with nature pictures, a reflection task, an informative video about the bio-economy and normative information (Cialdini et al., 2006; Nolan et al., 2008; Hahnel et al., 2014; Klaiman et al., 2016; Cox et al., 2019). This thesis not only replicated the assessment of these green nudges in the bio-economy context. It also provides the first comparison of the effectiveness of different green nudges which differ according to the internal motivation that they aim to activate. Results indicate that green nudges that activate beliefs and social norms are most effective. This is in line with the VBN theory assuming that variables in the end of the chain have stronger impacts on behavior (Stern et al., 1999) - or hypothetical WTP which this research uses as a proxy for behavior.

Third, in order to understand farmers' interest in bio-economy practices, this thesis extends the VBN theory (Stern et al., 1999) by farmers' perception of contextual factors. In this vein, farmers were asked how they evaluate the suitability of contextual factors for implementing the practice to valorize by-products. Based on Horbach (2008), these factors are represented by the market demand of biomass, future bio-economy policies and technological developments. Integrating these factors into the VBN theory, results show an increase of the model's predictive variance. More importantly, farmers' perceptions of contextual factors are positively associated with the strength of their ecological worldview, thus indicating a relationship between internal belief systems and external circumstances (Guagnano et al. 1995). From a theoretical perspective, it is assumed that farmers' ecological worldview influences how they perceive contextual factors (e.g. Baum and Gross 2017; Otten et al. 2017), but the direction of causality remains unclear. Further studies thus need to employ an experimental and a control group where participants in the experimental group are provided with a task or information to activate an ecological worldview. Thereby, it would be possible to assess the causal impact of an activated ecological worldview on farmers' perception of contextual factors (e.g. Steg and de Groot, 2010). However, the finding of this thesis provides first empirical evidence for the benefits of integrating contextual factors into the VBN theory.

Fourth, this thesis reveals that the integration of systems thinking could improve the NAM (Schwartz, 1977) in explaining consumer intention to buy bio-based products. Into more detail, systems thinking positively influences consumer problem awareness and outcome efficacy which, in turn, affect their personal norms and purchase intention. Results even indicate that adding

altruism and an ecological worldview to the model does not increase the predicted variance. As the existing VBN theory explains pro-environmental behavior based on altruism, an ecological worldview and the NAM (Stern et al., 1999), one implication of this finding is that the VBN theory could be condensed by replacing altruism and an ecological worldview by systems thinking. This is supported by results showing that systems thinking is strongly associated with altruism and an ecological worldview indicating that they explain a similar belief system (Davis and Stroink, 2015; Ballew et al., 2019). However, this assumption still needs empirical evidence from other domains.

Finally, this thesis provides the first study that explores whether the effectiveness of green nudges depends on consumers' cognitive styles. This adds on the theoretical assumption that behavior is influenced by external and internal factors acting in combination (Guagnano et al., 1995). Results indicate that consumers who base their decisions on their emotions react differently to green nudges than consumers who base their decisions on rational arguments. For instance, nature pictures seem to influence emotional decisionmakers, whereas the reflection about environmental consequences seem to trigger rational decisionmakers. However, more evidence is still needed in order to develop a profound theory about the interaction of green nudges and the cognitive style of the consumer.

5.2.2 Methodological contributions

From a methodological perspective, the contributions of this thesis can be structured into five main points. First, this thesis connects the methodology of a DCE with a between-subject design. The combination of both approaches enables investigating the effectiveness of green nudges on consumer WTP for cherry tomatoes with bio-based plastic packaging. This replicates the experimental design of few existing studies in consumer research who also combine both approaches (e.g. Kim et al., 2018).

Second, in order to analyse the quantitative data, this thesis adapts PLS-SEM, regression-based mediation analysis and RPL models. These methods are widely used in current empirical studies (e.g. Caputo et al., 2013; van Loo et al., 2015; Kamrath et al., 2018; Pacheco et al., 2018; Xiao and Hong, 2018; Xie et al., 2019). However, this thesis contributes methodologically by validating the applicability of this data analysis techniques aiming at understanding innovation adoption behavior.

Third, this thesis adds to research methods in the area of innovation adoption by using farmers' motivation to gather more information as the dependent variable. Based on the adoption decision process (Rogers, 2003), this variable is modelled as a precondition for the formation of an attitude towards the innovation which ultimately leads to a decision about whether or not to adopt it. As farmers are not familiar with the bio-economy practice to valorise by-products, an investigation of their interest is more appropriate than an assessment of their intention to adopt this practice. This idea has already been implemented by Wolske et al. (2017) in terms of interest in adopting residential solar photovoltaic systems. However, this thesis provides the first study which uses this approach to assess farmers' adoption decisions which might encourages other researchers who want to study the adoption of innovations which are not on the market yet.

Fourth, in order to improve the analysis of the DCE data, the RPL model is extended by adding a normally distributed random error component with zero mean in the estimation following previous studies on consumer preferences for sustainable labels (Caputo et al., 2013; Van Loo et al., 2015). This respondent-specific idiosyncratic error component is only associated with the experimentally designed product alternatives but not with the no-buy alternative. This approach allows to account for the assumption that the utilities of the purchase options might correlate between each other but not with the no-purchase option (Scarpa et al., 2005).

Finally, this thesis develops and tests a treatment to activate systems thinking (chapter 3). In this treatment, consumers are asked to list the consequences which they perceive 1) following their usual buying decisions and 2) if they purchased bio-based products more frequently. This task is assumed to activate respondents' systems thinking perspective as it draws their attention to the interconnectedness between their own behavior and external consequences (Hmelo-Silver et al., 2017; Cox et al., 2019). As participants in the treatment group report higher values in systems thinking than those participants in the control group, the treatment is assumed to be successful in activating a systems-thinking perspective. Moreover, the same treatment successfully serves as a green nudging strategy to increase WTP for bio-based packaging (chapter 4).

5.2.3 Empirical contributions

The empirical contributions of this thesis are threefold. First, the conducted studies provide empirical support for the effect of internal motivations and of contextual factors on the decision to adopt bio-economy innovations. Hence, this thesis generally replicates existing research in the area of pro-environmental innovation adoption (e.g. Steg et al., 2005; Horbach, 2008; Wolske et al., 2017) and adds empirical studies in the context of the bio-economy.

Second, the conducted studies provide evidence for the role of the VBN-theory and systems thinking for the decision to adopt bio-economy innovations. To date, support for the relevance of the VBN-theory can only be found in the wider context of the adoption of pro-environmental innovations. For examples, existing studies investigate consumer acceptability of energy policies (Steg et al., 2005), recycling behavior (Aguilar et al., 2013) as well as WTP for park conservation (López-Mosquera and Sánchez, 2012), and assess farmers' intention to adopt practices related to natural resource management (Seymour et al., 2010) and land management (Price and Leviston, 2014). Similarly, systems thinking is currently only applied to explain general pro-environmental beliefs and behaviors (Davis and Stroink, 2015; Lezak and Thibodeau, 2016; Ballew et al., 2019). Thus, by empirically studying the VBN theory and systems thinking in the context of the bio-economy, this thesis provides valuable domain-specific insights relevant to the bio-economy.

Third, this thesis assesses and compares the effectiveness of green nudges while taking consumer WTP for bio-based plastic packaging as the empirical example. Based on existing literature, these strategies are designed to activate consumers' pro-environmental values, worldview, beliefs and social norms (Cialdini et al., 2006; Nolan et al., 2008; Hahnel et al., 2014; Klaiman et al., 2016; Cox et al., 2019). Currently, these green nudges are only investigated in studies that aim to explain environmental behavior. For example, the technique to prime pro-environmental values by providing nature pictures is only assessed to enhance donating behavior (Verplanken and Holland, 2002), to lower price sensitivity for elective vehicles (Hahnel et al., 2014) and to stimulate organic food purchases (Bullock et al., 2017). In terms of an ecological and systemic worldview, no current studies exist which explore the activation of these internal motivations. More studies can be found in the context of providing consumers with relevant information to increase their willingness-to-pay for environmentally-friendly products (Francisco et al., 2015; Klaiman et al., 2016, 2017; Lusk, 2018). Moreover, existing studies suggest that providing normative information is able to mobilize action against social and pro-environmental problems (Parks et al., 2001; Cialdini et al., 2006;

Nolan et al., 2008). Hence, this thesis closes a relevant research gap by applying green nudges to explore their impact on consumer WTP for bio-based plastic packaging.

5.3 Practical contributions

This thesis generally contributes to the development of scientifically sound strategies to foster the transition from a fossil-based towards a bio-based economy. In this vein, it focuses on farmers' and consumers' willingness to adopt bio-economy innovations. However, although the adoption of this type of innovations would be an important and beneficial outcome, it will probably not lead to transformational change of the economic system (e.g. Abson et al., 2017). System change is rather generated by changing the underlying beliefs of the actors as they ultimately influence the overall direction and behavior of the system (Meadows, 1999; Geels, 2004; Abson et al., 2017). As such, this thesis also provides insights about internal values and cognitive paradigms that might be beneficial for the bio-economy transition.

Figure 5.2 visualizes the practical implications of this thesis by classifying them according to their degree of leverage for overall system change towards a bio-economy. To illustrate, the first group of interventions only aims to speed up the diffusion of innovations among promising target groups, which means they have limited power to influence potential adopters outside of these groups. The second group of interventions aims to influence innovation-decisions of people by nudging them to adopt bio-economy innovations. These interventions have a broader impact than the previously mentioned ones, but might have limited long-term effects. According to Meadows (1999), interventions have the strongest leverage effect on system change when they aim at changing people's underlying values and cognitive paradigms. In addition, Figure 5.2 illustrates the suggestions for policymakers and for industry representatives which the following sub-sections also explain into more detail.

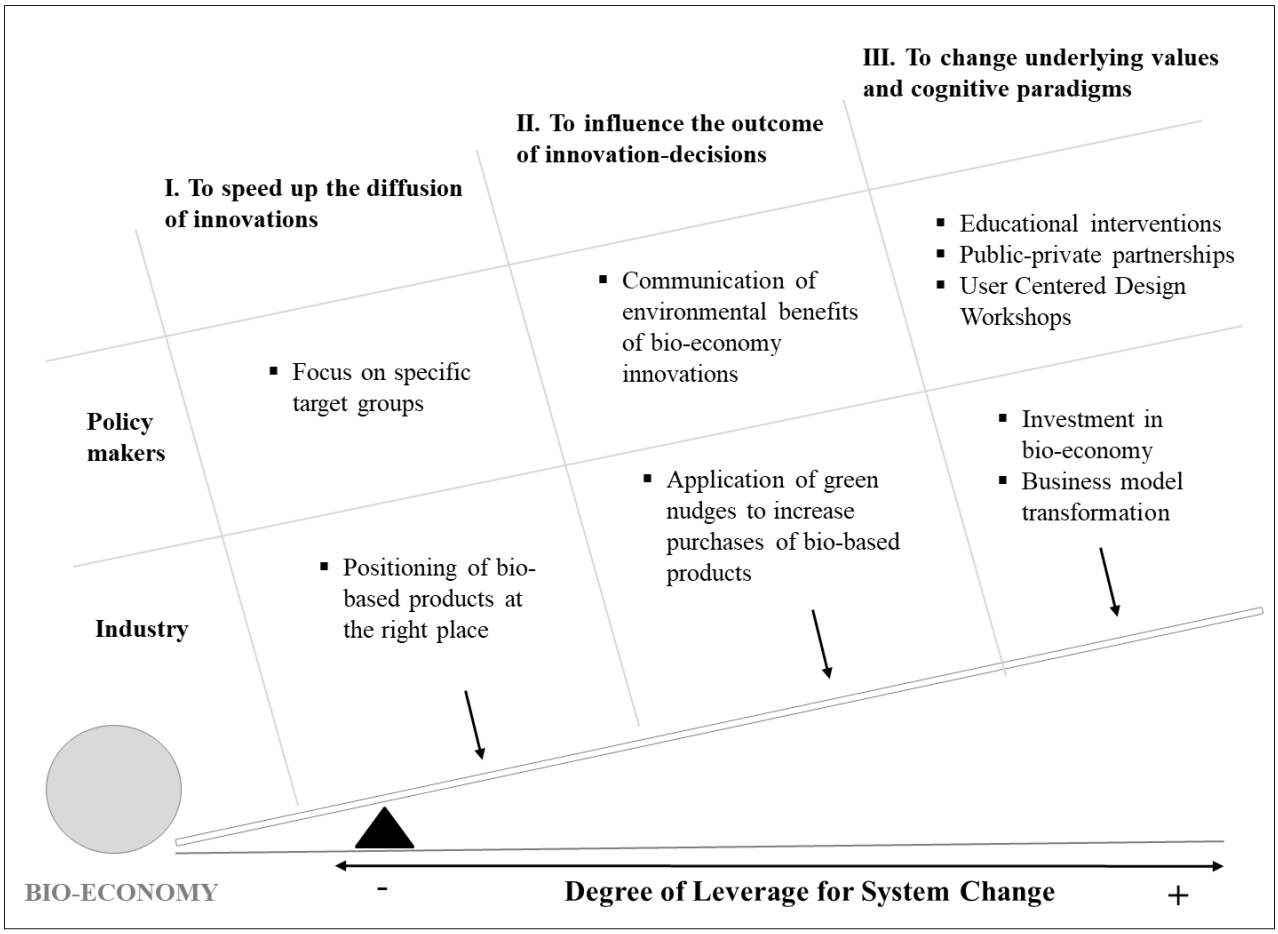

Figure 5.2. Overview of the practical implications.

Source: Own illustration based on Abson et al. (2017).

5.3.1 Implications for policymakers

Current bio-economy policy strategies (Federal Ministry of Education and Research, 2011; Federal Ministry of Food and Agriculture, 2014) fail to address one critical influencing factor for the bio-economy transition which is the willingness of value chain actors to adopt novel technologies, practices and behaviors (Bröring et al., 2017). In order to improve these strategies, this thesis identifies three major implications for policymakers.

First, this thesis contributes to the development of a profile of farmers who are most interested in bio-economy practices. At least, results indicate that those farmers who are more altruistic, aware of environmental consequences, open to change, and with a stronger ecological worldview are

more likely to be interested in the practice to valorize by-products (chapter 2). This profile can be used by farmer's associations in order to target promising groups of farmers with information about the bio-economy. Moreover, scientists could use this profile to identify farmers who might be willing to test novel bio-economy practices on their farms. Thereby, different institutions can speed up the diffusion of innovations as those farmers who are already interested receive information which they need to form an attitude to ultimately make an adoption-decision (e.g. Rogers, 2003). In practice, farmers who have already adopted organic or innovative farm practices could act as a potential target group. This can be justified by results indicating that organic farmers are more driven by social and moral concerns (Mzoughi, 2011), while innovative farmers are generally more open to change (Kemp et al., 2014). Beyond that, these farmers might even act as "opinion leaders" and influence their colleagues to also adopt bio-economy practices (Case, 1992; Rogers, 2003).

Second, in order to influence the outcome of innovation-decisions, policymakers not only need to communicate the financial benefits of bio-economy innovations, but also need to establish their broader environmental relevance. To illustrate, results indicate that farmers (and potentially also managers) are more likely to be interested in bio-economy practices if they believe that this practice effectively reduces environmental threats (chapter 2). Moreover, consumers who are aware of the environmental problems of fossil resources report higher intentions to buy bio-based products (chapter 3). Consumer are even willing to pay more for tomatoes with bio-based packaging after receiving information about the environmental benefits of the bio-economy (chapter 4). These findings indicate that greater information about the beneficial environmental impact of bio-economy innovations could serve as both valuable information and additional motivation to undertake the necessary behavioral changes. Hence, companies could provide information on their products or on their websites, e.g. by presenting results of life-cyle analyses indicating the environmental impacts of their products. Moreover, farmer's associations need to provide farmers with information about the environmental consequences of bio-economy innovations.

Third, interventions to change value chain agents' values and cognitive paradigms could help to stimulate the bio-economy transition. For instance, findings indicate that altruism and an ecological worldview are positively associated with farmers' interest in bio-economy practices (section 2). Both altruism and an ecological worldview are also found to be related to consumer intention to purchase bio-based products (section 3). More importantly, their purchase intention is strongly affected by consumers' degree of systems thinking which seems to be an important cognitive

paradigm in the overall bio-economy transition (Urmetzer et al., 2020). Although values and paradigms are relatively stable across time and context (Rokeach, 1980), schools and universities need to offer environmental education programs in order to generate a cultural transition starting with the young generations (Pooley and O'Connor, 2000). For instance, outdoor activities such as hiking and camping have been shown to foster an increased perceived connectedness with nature, and thereby promoting a more ecological worldview (Schultz, 2000). Moreover, systems thinking could be taught by making use of teaching didactic such as role-plays (Sterman et al., 2015) or conceptual representations and diagrams (Hmelo-Silver et al., 2017; Cox et al., 2019). Outside of the education system, one possibility to cultivate openness to change and pro-environmental values among farmers might be to stimulate public-private partnerships in which people with different perspectives discuss sustainability issues and novel agricultural practices (Ngutu and Recke, 2006; Carraresi et al., 2018; Luís et al., 2018). Moreover, farmers could be intergrated in the early phase of bio-economy research projects by conducting user-centered design workshops. Thereby, scientists are able to also consider their ideas and needs in the development of bio-economy innovations which might enhance their market success later on (Gruner and Homburg, 2000; Hippel and Katz, 2002; Cui and Wu, 2017). Moreover, the interaction with scientists might also increase farmers trust in the honesty and concern of scientists which, in turn, might increase their willingness to adopt innovative farm practices (e.g. Liu et al., 2020).

5.3.2 Implications for industry managers

Even though the bio-economy generally receives public support, many industrial regions still do not fully take advantage of the innovations associated with this novel concept (Spatial Foresight, SWECO, ÖIR, t33, Nordregio, Berman Group, Infyde, 2017). This phenomenon might occur because novel bio-economy innovations are still not profitable for companies due to high research and development costs as well as low oil prices (e.g. Vandermeulen et al., 2012; Carus et al., 2014; Jernström et al., 2017). Thus, industry managers are currently not willing to change their business model and to invest in novel bio-economy technologies (Carraresi et al., 2018). In this vein, this thesis proposes three main suggestions in order to tackle this issue.

First, this thesis identifies characteristics of consumers who are likely to purchase bio-based products. Against this backdrop, results indicate that consumers with altruistic values and an ecological worldview increasingly intent to buy this type of products (chapter 3). This finding can

be used by companies who want to place their bio-based products in the market. For example, consumers who purchase organic foods are found to be more environmentally concerned than consumers who purchase conventional foods (Kushwah et al., 2019). Hence, it makes sense to position bio-based products such as cosmetics or detergents in organic grocery stores. Moreover, bio-based plastic packaging might be particularly appreciated by consumers in combination with organic foods (chapter 4).

Second, in order to influence consumers' decisions to adopt bio-based products, companies need to adopt green nudging strategies as suggested by behavioral economics (e.g. Thaler and Sunstein, 2008; Schubert, 2017). In this regard, the results of this thesis provide evidence for the effectiveness of green nudges in increasing consumer WTP for cherry tomatoes with bio-based plastic packaging (chapter 4). The underlying idea is to implement these cues or primes into the context in which consumers are situated when making their purchase decision. For example, product designs could integrate pictures of the environment to activate pro-environmental values (e.g. Hahnel et al., 2014). Moreover, it is recommended to certify bio-based products by appropriate labels and to make them more recognizable for the consumer (chapter 4). In practice, companies can use already existing labels in the market from certifiers such as DIN CERTICO or TÜV AUSTRIA (European Bioplastics, 2019). Moreover, brochures could deliver information or provide reflection question about environmental consequences to activate a systems-thinking perspective (chapter 3). In addition, companies need to invest in social media strategies (Muninger et al., 2019), e.g. by hiring influencers which provide social proof of bio-based products (chapter 4). However, the findings of this thesis also highlight that marketers need to take the different cognitive styles of consumers into account. Hence, companies are either recommended to use green nudges which are effective for both intuitive and rational decision-makers or they choose the green nudge in line with the specific target group (chapter 4).

Third, this thesis generally encourages companies to invest in the concept of a bio-based economy. For example, this thesis found that farmers are interested in bio-economy practices to valorize by-products indicating that they are willing to cover the biomass demand of the industry (chapter 2). Moreover, consumers generally intend to purchase bio-based products (chapter 3) which is in line with prior consumer studies (Scherer et al., 2018a; Klein et al., 2019). In addition, consumers are found to be even willing to pay a price premium for bio-based packaging which indicates that the food industry could adopt bio-based plastic packaging without needing to reduce their usual profit

margin (chapter 4). However, it needs to be noted that bio-based plastics are currently predominantly manufactured using annual crops including corn, sugar beet or cassava (Pandit et al., 2018). Potential conflicts with food and feed production have led critics to raise questions about the overall sustainability of bio-based plastics (Posen et al., 2017). Escobar et al. (2018), therefore, suggest to use second generation feedstocks like plant residues or organic wastes as raw materials. For example, by-products from soy oil production can be utilized to produce bio-based packaging films (Wang and Wang, 2017). As research and technology in the utilization of by-products are getting more and more advanced (Sims et al., 2010), it is assumed that bio-based plastic will mainly be derived from second generation feedstocks in the future. Beyond that, it would be favorable if companies do not only invest in the bio-economy because of its great business potential. In line with the sustainability transition, companies need to change their operating paradigms to transform their business models in order to tackle the food and energy demand of the growing world population and to deal with depleting fossil resources (Meadows et al., 2004; Godfray et al., 2010; Augustin et al., 2016). Thereby, the bio-economy concept provides a great opportunity to combine economic growth and sustainability (European Commission, 2012; Lewandowski et al., 2018).

5.4 Limitations and directions for further research

Despite important scientific and practical contributions, this thesis has also some limitations which suggest several avenues for future research. These limitations can be structured into theoretical, methodological and empirical drawbacks as depicted in Table 5.2.

Table 5.2. Limitations of the thesis and future research avenues.

	Limitations	Future research avenues
Theoretical	▪ Focus on internal behavioral motivations as drivers for adoption-decisions ▪ Lack of addressing the effect of prior beliefs in the DCE	▪ Extension of models by external factors ▪ Assessment of beliefs before and after treatments
Methodological	▪ Self-selection bias ▪ Correlational study designs ▪ Self-report measures	▪ Appropriate control groups ▪ Experimental designs ▪ Direct measurement tools
Empirical	▪ External validity issues ▪ Cross-sectional data ▪ Use of proxies to measure adoption behavior ▪ Focus on farmers and consumers	▪ Studies in other domains ▪ Longitudinal studies ▪ Observation of actual behavior ▪ Studies with industry representatives

5.4.1 Theoretical limitations

This thesis is theoretically limited in two important ways. First, it is limited by its main focus on internal behavioral motivations as drivers for adoption-decisions. Even though the first study extends the VBN theory with variables that depict farmers' perception of contextual factors (chapter 2), the impacts of existing policy measures, the actual market demand of biomass and technologically developments are not investigated. Similarly, the study that focuses at the impact of systems thinking on consumer intention to purchase bio-based products (chapter 3) does not assess the effects of the specific product characteristics as well as of the potential purchase situation. However, these limitations are addressed in the third study which focuses on consumer WTP for bio-based plastic packaging (chapter 4). Nevertheless, further studies need to extend their

models to explain adoption behavior in the bio-economy context by relevant contextual factors, e.g. as depicted by Horbach (2008; 2012).

The second theoretical limitation of this thesis is that the DCE study design (chapter 4) does not consider the impact of prior pro-environmental beliefs on the effectiveness of the green nudges. For example, past studies indicate that people are more susceptible to nature pictures and to information about the environment if these are in line with their beliefs (Hahnel et al., 2014; McFadden and Lusk, 2015; Vainio et al., 2018). Thus, future studies need to examine these assumptions by assessing consumer beliefs before and after the treatments.

5.4.2 Methodological limitations

From a methodological perspective, this thesis has three common limitations. First, the data samples in this thesis might have suffered from self-selection bias. To illustrate, in the first study only 35 % of the contacted farmers were willing to participate in the telephone interview (chapter 2). In the second study, more drop-outs are observed in the treatment group compared to those in the control group (chapter 3). Consequently, these self-selections might have been systematic and, thus, confounded the results of these studies. Future studies need to tackle this issue by investigating whether there actually exists a difference in adoption-decisions between individuals who are willing to participate in research studies and those who are not. Moreover, studies which use experimental designs need to develop appropriate control groups with similar time and cognitive effort compared to the treatment group. Thereby, the drop-outs of respondents might remain constant in the control and treatment groups.

The second methodological limitation refers to the correlational nature of the study designs. For incidence, the first study in this thesis investigates the relationship between farmers' ecological worldview and their perception of contextual factors (chapter 2). Although results indicate a positive association between those variables, the causal direction remains unclear. The second study explores the mechanism of systems thinking by assuming specific sequences in the estimation of mediation models (chapter 3). In the same way, the underlying correlational study design does not allow to draw causal inferences. Hence, other directions of causality are still possible and need to be investigated using relevant experimental research designs. For example, further studies could provide participants with different tasks or information to activate relevant

variables such an ecological worldview (chapter 2) or altruism (chapter 3) to explore the causal effects more closely.

Third, this thesis consists of the utilization of self-report measures to depict farmers' and consumers' values, ecological worldview, beliefs, norms and systems thinking (chapter 2, 3). Most of these measures are based on validated measures from the literature; however, convergent validity tests are still missing for the additional measures which are created to capture farmers' perception of contextual factors. Beside this problem, the main constraints of the general use of self-report measures are common method variance and social desirability issues. Both issues might cause that the observed relationships between the variables are overestimated. Moreover, although Milfont (2009) argues for a diminishing effect of social desirability on self-reported environmental attitudes and behaviors, future studies need to apply direct measurement tools. For example, these studies could make use of decision-making tasks (e.g. Thibodeau et al., 2016), implicit-association tests (e.g. Panzone et al., 2016), neuropsychological measures (Fulmer and Frijters, 2009) or mental modeling (Gray et al., 2012; Gray, 2018).

5.4.3 Empirical limitations

Due to the sampling and data collection procedure, this thesis suffers from four empirical limitations. First, the empirical studies in this thesis are conducted with certain value chain actors (i.e. farmers and consumers), in specific countries (i.e. Germany and USA) considering selected bio-economy innovations (i.e. the valorization of by-products, bio-based products and bio-based plastic packaging). However, the effect of internal behavioral motivations might vary across value chain actors, regions and innovation types, e.g. according to the culture (Hofstede et al., 2002) or national policy contexts (Prokopy et al., 2015; Butkowski et al., 2017). For example, European citizens might be more open to bio-economy innovations than US citizens as European bio-economy strategies already implemented subsidies and information campaigns (Dietz et al., 2018). Thus, in order to improve the external validity of the findings of this thesis, future studies are highly desirable to replicate the studies with other value chain actors, bio-economy practices and in other parts of the world.

Second, all three empirical studies in this thesis utilize cross-sectional data. As this data is based on observations of many participants at one point in time (e.g. Stangor, 2015), future studies need to conduct longitudinal studies which observe farmers' and consumers' adoption behavior over a

long period of time. For example, it would be beneficial to know whether farmers who state to be interested in bio-economy practices also adopt this practice in the future (chapter 2). Similarly, it remains unclear whether the effects of the treatment to activate systems thinking or of the green nudges to increase consumer WTP are only short-term. Therefore, more research is needed considering the long-term effects of the treatments (chapter 3, 4). In this case, longitudinal studies could assess consumer WTP over several days or months after the treatments.

Third, this thesis makes use of proxies to measure adoption behavior. For example, interest in bio-economy practices is a necessary but not sufficient condition for farmers to adopt these practices (chapter 2). In addition, the second study investigates consumer intention to buy bio-based products as a proxy for actual purchasing behavior (chapter 3). Finally, the third study uses a hypothetical choice experiment to make assumptions about consumer WTP for bio-based packaging (chapter 4). These measures might be good predictors of actual behavior (e.g. Morrison, 1979), but potential for bias still exists. Hence, once the selected bio-economy innovations are on the market, future studies need to validate the results of this thesis by observing the actual adoption behavior of farmers and the actual purchase decisions of consumers.

Finally, this thesis focuses only focuses on the first and on the final actors in the agri-food value chain, namely consumers and farmers. However, industry representatives also play a great role for the transition from a fossil-based towards a bio-based industry (Theinsathid et al., 2011; Vandermeulen et al., 2012; Berg et al., 2018). Thus, future studies also need to explore how internal behavioral motivation drive managers from chemical, packaging and food companies as well as retailers to adopt bio-economy innovations.

5.5 Conclusion

In the framework of this thesis, three empirical studies are conducted to explore how internal behavioral motivations drive consumers' and farmers' adoption of bio-economy innovations. Findings provide evidence that the seminal Value-beliefs-norms theory is an important framework to understand farmers' interest in bio-economy practices. Thus, policy-makers need to focus on increasing farmers' pro-environmental values, beliefs and norms in order to speed up the diffusion of bio-economy innovations. From a consumer perspective, results indicate that systems thinking seems to drive the intention to purchase bio-based products, and that a systems thinking perspective can be activated by asking consumers to reflect about their consumption behavior. Hence, the bio-economy transition could benefit from strategies which increase people's sense of complexity and interconnectedness such as the presented reflection task or educational interventions. Finally, this thesis compares the effectiveness of different green nudges on consumer willingness-to-pay for cherry tomatoes with bio-based plastic packaging. These green nudges are designed to activate different internal motivations such as biospheric values, systems thinking, pro-environmental beliefs and social norms by providing consumers with nature pictures, reflection questions, information about the bio-economy and normative information. Results indicate that the susceptibility of these green nudges depends on the decision-maker's cognitive style. Thus, food companies need to take the different cognitive styles of consumers into account when developing strategies to increase demand for food with bio-based plastic packaging. Overall, this thesis aims to motivate policy-makers, industry representatives and scientists to consider and to explore the impact of internal behavioral motivations on people's decision to adopt bio-economy innovations more closely.

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Appendix

Appendix A – Overview of studies in the literature review (Chapter 1).

Appendix B – Indicators of latent variables (Chapter 2).

Appendix C – Results for the evaluation of the measurement model (Chapter 2).

Appendix D – Correlation of latent constructs (Chapter 2).

Appendix E – Informative text in the survey (Chapter 3).

Appendix F – Voluntary additional information in the survey (Chapter 3).

Appendix G – Variable means, standard deviations and confidence intervals (Chapter 3).

Appendix H – Results for the covariates in the mediation analyses (Chapter 3).

Appendix I – Choice experiment instruction and cheap talk script (Chapter 4).

Appendix J – Provided information in treatment groups (Chapter 4).

Appendix K – Consumption habits by treatment groups (Chapter 4).

Appendix A. Overview of studies in the literature review.

No.	Publication	Value Chain Actor	Country	Variable of interest	Method	Significant drivers
1	Bartolini & Viaggi (2012)	Farmer	Italy	Willingness to adopt energy crops	Modeling	Agricultural policies
2	Case et al. (2017)	Farmer	Denmark	Willingness to use organic waste as fertilizer	Survey	Age, Farm size, organic/conventional farming
3	Rossi & Hinrichs (2011)	Farmer	US	General perception of bio-economy	Expert interviews	Skepticism about social impacts
4	Tur-Cardona et al. (2018)	Farmer	Belgium, Denmark, France, Netherlands, Germany, Hungary and Croatia	Willingness to purchase bio-based fertilizer	DCE	Attributes of the product (price, nitrogen content)
5	Berg et al. (2018)	Industry	Germany	Perceptions of drivers of biomass based value chains	Group concept mapping	Resource availability, R &D, Networking, Societal awareness, Policies, Market (prices)
6	Carraresi et al. (2018)	Industry	Germany	Perceived challenges for emerging value chains in bio-economy	Expert interviews	Regulations, missing competencies, networking
7	Leban et al. (2016)	Industry	Slovenia	Factors driving the use of forest-biomass for energy	Expert interviews	Policy instruments, market prices
8	Lopolito et al. (2015)	Industry	Italy	Effect of different policy strategy scenarios on local bio-based industry	Fuzzy cognitive maps	Policy strategies
9	Peuckert & Quitzow (2017)	Industry	France, Germany, the Netherlands, Italy, Belgium	Acceptance of bio-based products	Delphie approach	Eco-labeling/ bio-based content
10	Theinsathid et al. (2011)	Industry	Thailand	Factors affecting the adoption of bioplastics	Expert interviews	Policy factors (subsidies, grants, mandatory use), Competitive advantage, consumer demand, Image/ CSR, Cost savings

11	Vandermeulen et al. (2012)	Industry	Belgium	Expectations of bio-economy	Expert interviews	societal awareness (prices) R&D Policy regulation
12	Golowko et al. (2019)	General Public	Germany	Perception of bio-economy	Survey	Missing knowledge about bio-economy
13	Lynch et al. (2017)	General Public	The Netherlands	Perception of bio-based innovations	Focus Group	Economic growth, sustainability, Engagement with technologies, perceived personal benefits, transparency of lifecycle
14	Mukonza (2017)	General Public	South Africa	Perceptions of bio-fuels	Interviews	Societal awareness/ Information about benefits of biofuels
15	Sleenhoff et al. (2015)	General Public	The Netherlands	Emotional viewpoints about bio-economy transition	Q methodology/ Survey	Environmental awareness, Optimism
16	Stern et al. (2018)	General Public	Austria	Perception of bio-economy	Interviews	Positive and negative associations, sustainable consumption
17	Butkowski et al. (2017)	Consumer	Germany	Acceptance of GMO technology	Experiment	Policy scenarios, product end use (bioenergy or food), Risk perceptions, trust
18	Herbes et al. (2018)	Consumer	Germany, France, US	Attitudes towards biobased packaging	Survey	Packaging attributes (Recyclability, Biodegradability, renewable origin)
19	Klein et al. (2019)	Consumer	Germany	Purchase intention of bioplastic products	Survey	Attitudes, Altruism, Green consumer values, innovativeness, subjective norm, product experience, interest in information
20	Koutsimanis et al. (2012)	Consumer	Germany	Purchase decision for food with bio-based packaging	Conjoint analysis	Bio-based packaging increases preference for product
21	Lenaerts et al. (2019)	Consumer	Belgium	Perception of insects in non-food products	Survey	Novelty seeking, Education level, Experience with insects, age

22	Onwezen et al. (2017)	Consumer	Denmark, Germany, Italy, Netherlands, Czech Republic, Slovenia	Intention to purchase bio-based products	Survey	Subjective ambivalence, emotions, perceived benefits, perceived risks, social norms, PBC (TPB)
23	Reinders et al. (2017)	Consumer	Denmark, Germany, Italy, Netherlands, Czech Republic, Slovenia	Intention to purchase bio-based products	Survey	Product attribute (fully or partially bio-based), brand attitude, environmental consciousness
24	Russo et al. (2019)	Consumer	UK	Intention to purchase bio-waste products	Survey	green self-identity, attitude towards bio-based product, age and past purchase experience of eco-friendly products
25	Scherer et al. (2017)	Consumer	Germany	Preferences for bio-based plastic toys	Choice experiment	Product attributes (price, origin of biomass), environmental awareness, innovativeness, nature relatedness, health consciousness
26	Scherer et al. (2018)	Consumer	Germany	Interest in bio-based sports equipment	Conjoint experiment	Product attributes (biobased content, CO2 label, regionally grown biomass), environmental awareness, nature relatedness, preference for organic food
27	Sijtsema et al. (2016)	Consumer	Czech Republic, Denmark, Germany, Italy, The Netherlands	General perception of bio-based products	Focus group discussion	Positive and negative associations with concept, product attributes (Price, appearance, packaging)

Appendix B. Indicators of latent variables.

Latent variables (Sources)	Indicators	
Interest (Wolske et al., 2017)	I_1	If I knew a farmer from my region who already collects horticultural by-products, I would be interested in learning more about the advantages and disadvantages.
	I_2	If I knew a company that recycles horticultural by-products, I would be interested to get more information.
	I_3	I am interested in contacts to other farmers who already collect horticultural by-products.
	I_4	I am interested in contacts to companies that take my horticultural by-products.
	I_5	The likelihood is very high that I will look for more information about the valorization of my horticultural by-products in the future.
Altruism (Stern et al., 1999)	A_1	A world at peace
	A_2	Social justice
	A_3	Equality among men
	A_4	Environmental protection
	A_5	Unity with nature
	A_6	Respecting the earth
Self-Interest (Stern et al., 1999)	SI_1	Authority and right to lead
	SI_2	Having an impact on other people
	SI_3	Wealth
Openness-to-Change (Stern et al., 1999)	OC_1	A varied life
	OC_2	Exciting experiences
	OC_3	Curiosity
Traditionalism (Stern et al., 1999)	T_1	Honoring elders
	T_2	Family
	T_3	Self-discipline
Ecological world view (Diekmann and Preisendörfer, 2016)	EA_1	It worries me when I think of the environmental conditions our children and grandchildren are likely to face.
	EA_2	Environmental problems are greatly exaggerated by environmental activists (R)
	EA_3	The majority of people are not acting environmentally friendly
	EA_4	If we go on like this, we will soon experience a major ecological catastrophe
	EA_5	When I read newspaper reports or television broadcasts about environmental problems, I often become outraged and angry
	EA_6	There are limits of growth that our industrialized world has already crossed or will reach very soon
Awareness of Consequences (Stern et al., 1999)	AC_1	Do you think that the “take-make-dispose” economy, where residuals are not being recycled, will cause problems for you and your family in the future?
	AC_2	Do you think that the “take-make-dispose” economy will cause problems for other people in the future?
	AC_3	Do you think that the “take-make-dispose” economy will cause problems for animals, plants and the biosphere in the future?

	AC_4	Do you think that climate change will cause problems for you and your family in the future?
	AC_5	Do you think that climate change will cause problems for other people in the future?
	AC_6	Do you think that climate change will cause problems for animals, plants and the biosphere in the future?
	AC_7	Do you think the dependency of our economy on fossil resources like oil or coal will cause problems for you and your family in the future?
	AC_8	Do you think that the dependency of our economy on fossil resources will cause problems for other people in the future?
	AC_9	Do you think that the dependency of our economy on fossil resources will cause problems for animals, plants and the biosphere in the future?
Personal norm (Stern et al., 1999)	PN_1	Farmers like me should participate in a circular economy where residuals and by-products are valorized.
	PN_2	I feel a sense of moral responsibility to work against climate change.
	PN_3	I feel a personal obligation to alleviate the dependency of our economy on fossil resources.
Perceived environmental effectiveness (Stern et al., 1999)	EE_1	If horticultural by-products from my farm get valorized, I will contribute to foster the circular economy.
	EE_2	If horticultural by-products from my farm get valorized, I will contribute to fight against climate change.
	EE_3	If horticultural by-products from my farm get valorized, I will contribute to reduce the dependency of our economy on fossil resources.
Future market demand (Horbach, 2008)*	MD_1	In the future, the general demand for biomass will increase.
	MD_2	In the future, it will be profitable to collect horticultural by-products and sell them to companies.
	MD_3	In the future, consumers will expect farmers to operate more sustainably.
	MD_4	In the future, food retailers will request farmers to operate more sustainably.
Future environmental policy (Horbach, 2008)*	EP_1	In the future, there will be laws to regulate the valorization of horticultural by-products.
	EP_2	In the future, subsidies for the collection of horticultural by-products will come into place.
	EP_3	In the future, there will be a growing number of policy measures to promote the industrial valorization of horticultural by-products.
	EP_4	In the future, it will be prohibited to leave or put horticultural by-products on the field.
Future technology developments (Horbach, 2008)*	TD_1	In the future, transport and storage processes between farmers and chemical companies will become more efficient.
	TD_2	In the future, there will be technical solutions to harvest fruits and by-products such as leafs at the same time.
	TD_3	In the future, scientists will identify further application fields for horticultural by-products.
	TD_4	In the future, the extraction process of valuable components from horticultural by-products will become more efficient.

Note: * we developed indicators ourselves on the basis of Horbach (2008)

Appendix C. Results for the evaluation of the measurement model.

Variables	Indicators	Loadings	Composite reliability	AVE
Altruism	A_3	0.81	0.79	0.56
	A_5	0.71		
	A_6	0.73		
Self-Interest	SI_1	0.72	0.84	0.73
	SI_2	0.97		
Openness-to-change	OC_2	0.96	0.75	0.62
	OC_3	0.56		
Traditionalism	T_1	0.54	0.76	0.52
	T_2	0.70		
	T_3	0.87		
Ecological worldview	EA_1	0.84	0.84	0.64
	EA_4	0.81		
	EA_6	0.75		
Awareness of Consequences	AC_1	0.73	0.91	0.60
	AC_2	0.74		
	AC_4	0.80		
	AC_5	0.85		
	AC_6	0.82		
	AC_8	0.77		
	AC_9	0.71		
Personal norm	PN_1	0.78	0.89	0.73
	PN_2	0.88		
	PN_3	0.90		
Perceived pro-environmental effectiveness	EE_1	0.90	0.95	0.86
	EE_2	0.94		
	EE_3	0.94		
Future market demand	MD_1	0.62	0.73	0.49
	MD_2	0.87		
	MD_4	0.55		
Future environmental policy	EP_1	0.63	0.81	0.52
	EP_2	0.64		
	EP_3	0.87		
	EP_4	0.72		
Future technology developments	TD_1	0.93	0.81	0.69
	TD_4	0.72		
Interest	I_1	0.86	0.93	0.72
	I_2	0.86		
	I_3	0.88		
	I_4	0.86		
	I_5	0.80		

Appendix D. Correlation of latent constructs.

Constructs	1	2	3	4	5	6	7	8	9	10	11	12
1 Altruism	-											
2 Self-interest	0.20	-										
3 Openness-to change	0.30	0.48	-									
4 Traditionalism	0.48	0.26	0.14	-								
5 Ecological worldview	0.41	-0.11	0.10	0.07	-							
6 Awareness of consequences	0.48	0.08	0.20	0.24	0.63	-						
7 Personal norm	0.52	-0.02	0.11	0.19	0.51	0.61	-					
8 Environmental effectiveness	0.42	0.29	0.23	0.22	0.24	0.35	0.45	-				
9 Future market demand	0.28	0.12	0.11	0.24	0.28	0.16	0.31	0.15	-			
10 Future environmental policy	0.20	0.14	-0.00	0.14	0.24	0.02	0.13	0.07	0.56	-		
11 Future technology developments	0.06	0.14	0.09	0.07	-0.06	-0.16	0.19	-0.04	0.52	0.40	-	
12 Interest	0.14	0.05	0.27	0.16	0.12	0.13	0.40	0.34	0.34	0.16	0.08	-

Appendix E. Informative text in the survey.

Bio-based products are products that are either wholly or partially derived from biomass. Biomass here refers to the residual materials from plants which are not otherwise used for food or feed.

Nowadays, textiles, plastic packaging, cleaning products or cosmetics are, among other products, predominantly produced by using chemicals which are based on fossil fuels (e.g. oil or gas). Thus, bio-based products provide a plant-based alternative to those conventional fossil derived products.

Some examples of bio-based products include: t-shirts made from coffee grounds, shoes from algae, toys from bioplastic, compostable shopping bags or plant-based paint, laundry detergents and body lotion.

Appendix F. Voluntary additional information in the survey.

The sustainability of bio-based products depends on multiple factors, such as source of biomass, design of production process, choice of disposal option, etc.

Using residual material as feedstock combined with sustainable production processes can lead to goods which are improved versions of traditional fossil-based alternatives or completely new items.

Thus, bio-based products can
- reduce the economy's dependence on fossil resources
- make a positive contribution to stop climate change
- reduce waste
- help create green jobs and
- help drive innovation.

If you want to get an idea of the wide variety of bio-based products already available, the product database from the US Department of Agriculture (USDA) can help you. The BioPreferred® Program promotes the purchase and use of bio-based products, which have a specified amount of bio-based content, including those making use of plant or animal resources. In its catalogue USDA designates the minimum content of bio-based materials used in products.

You can find the catalogue by clicking on the following link: USDA Catalogue.

Appendix G. Variable means, standard deviations and confidence intervals.

		CTRL	TREAT
Purchase Intention	*M* (*Std.)*	**4.513** (1.089)	**4.676** (1.044)
	CI	[4.372 – 4.636]	[4.529 – 4.838]
Systems Thinking	*M* (*Std.)*	**4.266** (0.562)	**4.405** (0.622)
	CI	[4.198 – 4.326]	[4.313 – 4.498]
Altruism	*M* (*Std.)*	**5.051** (0.811)	**5.078** (0.779)
	CI	[4.957 – 5.145]	[4.958 – 5.198]
NEP	*M* (*Std.)*	**4.621** (0.887)	**4.775** (0.913)
	CI	[4.520 – 4.722]	[4.623 – 4.912]
Problem Awareness	*M* (*Std.)*	**4.496** (1.283)	**4.719** (1.185)
	CI	[4.341 – 4.637]	[4.532 – 4.895]
Outcome Efficacy	*M* (*Std.)*	**4.275** (1.066)	**4.429** (0.997)
	CI	[4.145 – 4.396]	[4.283 – 4.575]
Personal Norm	*M* (*Std.)*	**4.124** (1.319)	**4.350** (1.243)
	CI	[3.961 – 4.273]	[4.170 – 4.549]
	N	278	168

Variable scores could range from 1 to 6, where 1 = strongly disagree, and 6 = strongly agree. Numbers in parentheses are Confidence Intervals (CI) using 1,000 bootstrapped means

Appendix H. Results for the covariates in the mediation analyses.

Hypotheses		Coeff (SE)	St.Coeff	t	p-value	LLCI - ULCI
H1	INFO → ST	0.09 (0.058)	0.070	1.476	0.141	-0.028 – 0.198
	INFO → PI	0.04 (0.011)	0.170	3.889	0.000	0.022 – 0.067
H2	INFO → ST	0.02 (0.052)	0.015	0.352	0.725	- 0.084 – 0.121
	INFO → PI	0.04 (0.011)	0.144	3.398	0.001	0.016 – 0.059
	TREAT → ST	0.13 (0.052)	0.109	2.564	0.011	0.031 – 0.233
	TREAT → PI	0.01 (0.011)	0.055	1.833	0.067	-0.002 – 0.042
H3	INFO → NEP	0.14 (0.076)	0.076	1.861	0.063	-0.008 – 0.291
	INFO → PI	0.04 (0.011)	0.148	3.501	0.001	0.017 – 0.060
	TREAT → NEP	0.06 (0.076)	0.030	0.736	0.462	-0.093 – 0.205
	TREAT → PI	0.01 (0.011)	0.038	0.903	0.367	-0.012 – 0.031
H4	INFO → PA	0.34 (0.107)	0.132	3.199	0.002	0.132 – 0.554
	INFO → OE	0.06 (0.072)	0.029	0.863	0.389	-0.020 – 0.205
	INFO → PN	0.09 (0.086)	0.033	1.041	0.299	-0.080 – 0.258
	INFO → PI	0.024 (0.010)	0.092	2.458	0.014	0.005 – 0.043
	TREAT → PA	0.112 (0.107)	0.043	1.042	0.298	-0.099 – 0.322
	TREAT → OE	0.005 (0.072)	0.002	0.063	0.950	-0.136 – 0.145
	TREAT → PN	0.067 (0.085)	0.025	0.792	0.429	-0.100 – 0.234
	TREAT → PI	0.005 (0.010)	0.021	0.556	0.579	-0.014 – 0.024

Note: St. Coeff = standardized coefficients, SE = standard error, LLCI = Lower level of 95 % confidence interval, ULCI = Upper level of 95 % confidence interval

Appendix I. Choice experiment instruction and cheap talk script.

‘Imagine you are shopping at your local grocery store. In what follows, we will ask you 8 different choice questions. Each choice question is represented by two options of packaged cherry tomatoes and a “no purchase” option. The tomatoes in both options are exactly the same except for the following attributes: price charged (0.99 €, 1.89 €, 2.79 €, 3.69 €), organically produced tomatoes (yes, no) and the type of packaging used, i.e. bio-based packaging (yes, no) and recyclable (yes, no) or compostable (yes, no). Any other characteristics of tomatoes that are not reported in the product profiles are identical across the two options. In both packages, there are 250g of tomatoes.

When responding to each choice question, please try to think the same way you would if you really had to pay for the product and take it home. So, imagine you are at the retailer of your choice and that you are looking for 250 grams of cherry tomatoes. When making your selection, consider whether you would actually be willing to pay the listed price, meaning that you would no longer have that amount available for purchases. Keeping this in minds, for each of the following choice questions, please choose ONLY one option of the packaged tomatoes you would prefer to purchase at the listed prices. Alternatively, you may choose NOT TO PURCHASE any product.’

Appendix J. Provided information in treatment groups.

BASIC

Consumers are exposed to a variety of labels and claims when shopping for food products. The following is a selection of such labels and claims. Please carefully read the information below which will help you in completing the questions that follow about tomato purchase decisions. Afterwards, we will check with your understanding of the text.

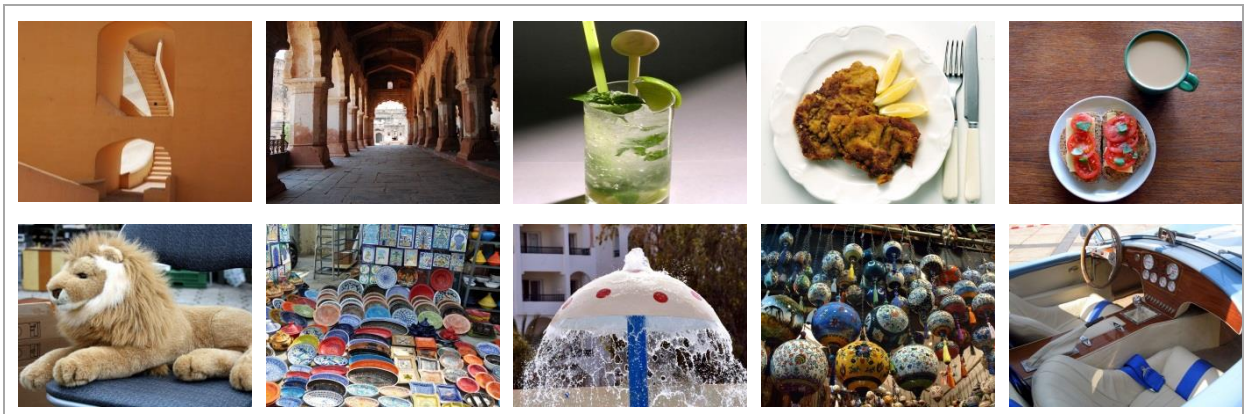
The Bio-Siegel marks organically produced products. The use of synthetic chemical fertilizers, and pesticides as well as preservatives is permitted.

This bio-based plastic label certifies packaging which is based on renewable resources. Plastic packaging with this label is produced on the basis of plant-based biomass (e.g. maize, gras, algae).

The recycling symbol certifies packaging which can be recycled. After disposal, plastic packaging with this label can be shredded, melted and reused to produce other products.

The Seedling label certifies packaging which is industrially compostable. Plastic packaging with this label is fully biodegradable in industrial composting plants under controlled conditions.

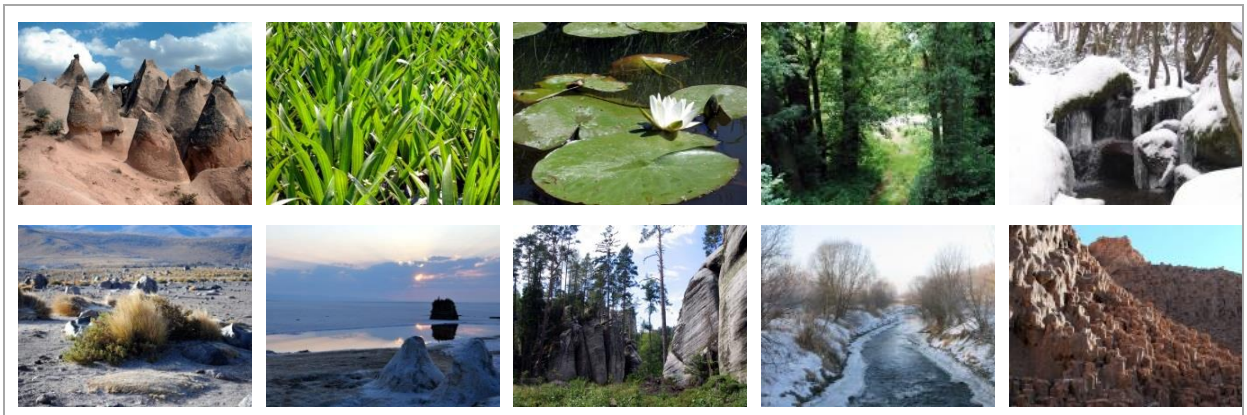
BASIC_V



How do you rate the attractiveness of this picture?

Not attractive at all	Not attractive	Moderately attractive	Attractive	Extremely attractive
☐	☐	☐	☐	☐

VALUE



How do you rate the attractiveness of this picture?

Not attractive at all	Not attractive	Moderately attractive	Attractive	Extremely attractive
☐	☐	☐	☐	☐

WORLDVIEW

Video script:

‘We dependent on fossil fuels - and not only when it comes to energy. Many everyday products such as plastics, paints and textiles are based on fossil oil. The problem is that oil production is harmful for the climate and fossil fuels are becoming scarce. In contrast to that, bio-based materials are renewable and much more environmentally friendly. Therefore, scientists are looking for new ways to make better use of plants, animals, microorganisms and even biological waste. They are developing new products with innovative properties for a wide variety of industries. This knowledge-based economic concept is called bio-economy. This means that companies use materials from renewable resources or rely on bio-based production processes, for instance by producing fuel with the help of microorganisms. The advantage is that if the bio-economy prevails, we can reduce greenhouse gas emissions and contribute to supplying the growing world population with food and preserve resources. The long-term goal of the bio-economy is a circular economy in which materials are used several times and produce as little waste as possible. Innovative bio-based products can already be found in our everyday lives: for example, clothes made of coffee grounds, computer screens made of sugar or fuel made of straw remains. As the bio-economy combines economic growth with sustainability, it is becoming increasingly important in everyday life and in politics in Germany, Europe and the world.’

(Link: https://www.bmbf.de/de/media-video-11043.html)

Reflection questions:

‘What does it mean for plastic?

Take 1 minute and 30 seconds and consider the consequences of plastic production for plants and animals as well as for the environment as a whole. Note that the button to advance is set to appear based on a timer to encourage your thoughtful deliberation.‘

‘Which consequences do you see for the environment following high amounts of fossil oil used for fossil-based plastic production?’

‘Which consequences do you see for the environment if not fossil oil but plant biomass is used to produce plastic?’

BELIEF

Video (same as in WVIEW)

Text:

‘What does this mean for plastic?

Conventional plastics are manufactured on the basis of petroleum. During this process, high amounts of CO2 emissions are released. CO2 is a greenhouse gas which prevents the heat on earth from escaping to space which is why the earth is continuously getting warmer.

Plastics can also be manufactured on the basis of plant biomass. Plants take the same amount of carbon oxide from the air as will be released during their later rotting. Their CO2 balance is, thus, balanced. Thus, substituting fossil oil with plant biomass could lead to a reduction of CO2 emissions in the manufacturing process of plastics.’

NORM

Text:

‘German consumers state bio-based plastic is important

According to the study conducted by the technical university of Munich (TUM) in 2016, German consumers highly appreciate bio-based plastics. In fact, 77,5 % of 1,191 questioned consumers state that bio-based plastics based are either important or very important to them. Moreover, the majority of participants in that study agrees that - compared to conventional petroleum-based plastics - bio-based plastics can reduce the dependency of fossil fuels and, in turn, reduce CO2 emissions.

You find more information about the study **here**.‘

(Link: https://d-nb.info/1125627026/34)

Appendix K. Consumption habits by treatment groups.

Variable	Total	CTRL	BASIC	BASIC_V	VALUE	WVIEW	BELIEF	NORM
How often did you buy cherry tomatoes during the past three months?								
> 2 times per week	**10.9**	14.1	13.0	11.6	12.3	6.7	11.6	6.7
1- 2 times per week	**42.0**	33.6	38.4	34.9	45.2	43.7	47.6	50.7
Every 2 weeks	**29.7**	31.5	28.1	34.2	28.8	33.3	23.1	29.3
Once a month	**16.5**	18.8	20.5	19.2	12.3	14.8	16.3	13.3
Other	**0.9**	2.0	-	-	1.4	1.5	1.4	-
How many grams of cherry tomatoes do you usually buy?								
250 g	**48.2**	38.9	48.6	55.5	45.9	49.6	48.3	50.7
500 g	**47.2**	53.0	46.6	39.0	48.6	46.7	49.0	47.3
Other	**4.6**	8.1	4.8	5.5	5.5	3.7	2.7	2.0
Where do you usually buy cherry tomatoes?								
Discounter	**40.5**	48.3	35.6	41.1	43.2	40.7	37.4	37.3
Supermarket	**51.3**	45.6	50.7	54.8	47.3	53.3	49.7	58.0
Other	**8.1**	6.0	13.7	4.1	9.6	5.9	12.9	4.7
How are the cherry tomatoes you buy usually packaged?								
Plastic	**77.2**	77.9	76.7	78.1	75.3	75.6	74.1	82.7
Paper	**11.7**	12.8	11.0	4.8	13.7	14.8	14.3	10.7
unpackaged	**11.1**	9.4	12.3	17.1	11.0	9.6	11.6	6.7
N	**1019**	149	146	146	146	135	147	150