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**Drivers of sustainable behavior:
Personality, training, and incentives**

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LIST OF ABBREVIATIONS

BMUB	Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety
IPCC	Intergovernmental Panel on Climate Change
RE	Renewable energy
SOEP	German Socio-Economic Panel
SRI	Socially responsible investment
UBA	Federal Environment Agency
WCED	World Commission on Environment and Development

1 Introduction

1.1 The need for behavioral economics in sustainability science

Striving for sustainable development across different facets of life has become a prominent and widely recognized social goal (Rands, Ribbens, Casagrande, & McIlvaine-Newsad, 2007; Starik & Kanashiro, 2013). This is reflected in the generally accepted, broad definition of sustainable development or sustainability (Husted, Sharma, & Starik, 2007), which was put forward by the World Commission on Environment and Development (WCED) in its report “Our Common Future”: “development that meets the needs of the present without comprising the ability of future generations to meet their own needs” (WCED, 1987, p. 43). Efforts to facilitate this development should not be restricted to addressing environmental issues. True sustainable development must consider three dimensions: economy, environment, and social equity; this is known as the “3 E’s” or “triple bottom line” approach (Elkington, 1998).¹

Across each of these dimensions, the ambiguity and complexity of sustainable development (Hoffman & Bazerman, 2007) implies a need for changes of many stakeholders’ behaviors on different levels, i.e., a multilevel and multi-system approach (Olsson, Galaz, & Boonstra, 2014; Rands et al., 2007). Actions undertaken willingly by individuals are an integral part of these large-scale approaches to realizing the required drastic societal changes (Carter, 2007). Understanding the drivers of individual decision-making and sustainability-related behavior in order to increase the pursuit of sustainability through personal choices is thus imperative and should be a cornerstone of the emerging field of “sustainability science” (Clark & Dickson, 2003; Kates et al., 2001). Positioned at the intersection of sustainability and behavioral economics, this doctoral thesis contributes to this goal by analyzing previously uninvestigated aspects of the influence of personality, training, and incentives in distinct situations of individual (un)sustainable behavior and decision-making.

¹ Cultural aspects are sometimes posited as a fourth pillar (Hawkes, 2001).

The behavioral sciences can play an important role in developing and evaluating possible ways to facilitate sustainable behavior and by informing stakeholders about effective measures (Marx & Weber, 2012; Shafir, 2012; Weber & Johnson, 2012). However, recent evaluations of existing research conclude that the role of choice and human behavior in environmental change has been under-emphasized, especially in research on energy-related decision-making and the economics of climate change (Brekke & Johansson-Stenman, 2008; Minsch, Goldblatt, Flüeler, & Spreng, 2012; Sovacool, 2014). This assessment underlines the need for greater interdisciplinary interaction and a broader social science research agenda. Over recent decades, the focus of environmental science has been on physical-mechanical systems, technological fixes, and conventional techno-economic thinking; this prevails because changing the environment while allowing people to maintain their existing lifestyles often seems more attractive than changing individual behavior (Heberlein, 2012; Lutzenhiser & Shove, 1999).

At the same time, economic models of choice that assume ideal, rational decision-makers remain prevalent in policy circles when discussing green growth and environmental change (Weber, 2012; Weber & Johnson, 2012). This is despite a broad consensus in behavioral science research that human decision-making and behavior are often shaped by contextual factors (Dolan et al., 2012), influenced by biases related to time horizons and uncertainty (Hardisty et al., 2012; Marx & Weber, 2012), and better characterized as “boundedly rational” due to cognitive and informational limitations (Simon, 1982). Assuming rational choice neglects the influence of these human elements. In contrast, policies and measures aiming to foster more sustainable decision-making and behavior should be developed based on the insight of behavioral sciences in order to be effective. In addition, if research is to drive sustainable change, traditional descriptive approaches of explaining and understanding observed phenomena must be complemented with prescriptive sustainability research that focuses on designing answers to experienced challenges (Becker, 2014).

Many methods for influencing environmentally impactful behavior have been well studied (Stern, 2000), but certain fields remain relatively untapped. In particular, there are few studies on non-financial elements of energy-related decision-making, be they in the form of non-monetary rewards for energy-efficient behavior (Barkenbus, 2010; Condy, Clark, & Stolovitch, 2003; Hammermann & Mohnen, 2014) or socio-psychological drivers of citizen-investors’ decisions to invest in renewable energy (RE) projects (Bergek, Mignon,

& Sundberg, 2013; Masini & Menichetti, 2013; Mathews, Kidney, Mallon, & Hughes, 2010; Yildiz, 2014). Further analysis of attempts to reduce the cognitive biases that perpetuate unsustainable practices, such as overconfidence, can help reduce socially and environmentally dysfunctional behavior (Flemming, Hilliard, & Jamieson, 2008; Hoffman & Bazerman, 2007). Despite the expansion of topics covered, assessments of the current state of research have identified a need for *methodological* expansion, such as using field research and controlled field experiments to collect data that can be used to develop effective measures for sustainable behavior (Metcalfe & Dolan, 2012; Sovacool, 2014).

In light of the need for further empirical research in these areas of behavioral science in order to inform current discussions on facilitating sustainable development, this thesis presents four empirical studies of energy-efficient behavior, overconfidence reduction, and personal motivations behind private RE investments.

1.2 Research questions and methodological approaches

In its four separate studies, this thesis responds to the call to incorporate behavioral science into the analysis of decision-making and the development of effective measures to elicit more sustainable behavior.

The initial focus is on the road transport sector. As the source of 17% of the world's total energy-related CO₂ emissions (Intergovernmental Panel on Climate Change (IPCC), 2014), this is an essential domain for analyzing energy consumption behavior. In addition, transportation research is still largely based on the paradigm of the rational actor, and behavioral economics has had relatively minor influence on research into transport-related behavior (Gaker, Zheng, & Walker, 2010). As such, there is a large need to integrate the insights of behavioral sciences into analyses of the effects of human behavior in transportation, as well as considerable potential for doing so (McFadden, 2007).

Previous studies of energy-efficient behavior and fuel-efficient driving have discussed different types of social, informational, and technically supported interventions (for an overview see Abrahamse, Steg, Vlek, & Rothengatter, 2005 and Santos, Behrendt, & Teytelboym, 2010). However, few researchers focus on changing individual energy consumption behavior in an organizational context (Carrico & Riemer, 2011; Lulfs &

Hahn, 2014; Nilsson, Andersson, & Bergstad, 2015; Siero, Bakker, Dekker, & van den Burg, 1996). Furthermore, the effects of rewards on energy behavior are still relatively unknown (Dolan & Metcalfe, 2013) and there are few comparative studies of the effects of monetary and non-monetary rewards. Indeed, the effects of rewards (especially non-monetary ones) for eco-driving in organizational settings remain unclear (Barkenbus, 2010). This is despite the fact that incentives have been proven effective in many different contexts (Garbers & Konradt, 2014; Webb & Sheeran, 2006) and research suggests that that they might work in the transport sector as well (Khademi & Timmermans, 2014; Liimatainen, 2011; Sierzchula, Bakker, Maat, & van Wee, 2014). In addition to a lack of studies of individual non-monetary incentives, previous research on energy conservation has mostly considered short-term effects of behavioral interventions. The gradient or variation in the impact of interventions on energy conservation behavior over time is still largely unexplored (as illustrated by Allcott & Rogers, 2014). In particular, the long-term effectiveness of reward schemes in terms of changing travel behavior remains unclear (Khademi & Timmermans, 2014). Thus, the first part of this thesis considers short- and long-term effects as it examines the research question:

(1) Can individual incentive mechanisms for professional drivers induce greater fuel efficiency (in the short and long terms) and do non-monetary incentives have a different effect on fuel consumption than monetary incentives?

The second part of the thesis considers eco-driving training, which is a popular approach to increasing fuel efficiency that has been widely analyzed. However, few of these studies extend over a time period longer than a few weeks or months (Beusen et al., 2009; Daun, Braun, Frank, Haug, & Lienkamp, 2013; af Wåhlberg, 2007; af Wåhlberg & Göthe, 2007). Furthermore, both researchers and training providers generally suggest that eco-driving training reduces fuel consumption but do not differentiate further (Austrian Energy Agency, 2013; Beusen et al., 2009; Cebrat, 2010; Haworth & Symmons, 2001; Reinhardt, 2001; Symmons, Grunstein, & Van Doorn, 2008; af Wåhlberg & Göthe, 2007). Thus, the extant scientific and practitioner-oriented literature differentiates little (or, at least, insufficiently) between different types of training (with the notable exception of Symmons, Rose, & Van Doorn, 2009). The final shortcoming in this area of research is that applying a combination of different measures to support proenvironmental behavior is often recommended (e.g., Bonsall, Conner, & Darnton, 2009; Gardner & Stern, 2002; Stern,

2000), but the potential interaction effects of knowledge-increasing measures such as training and economic incentives to stimulate eco-driving have not yet been examined. These related gaps in knowledge lead to the second research question:

(2) What are the long-term effects of eco-driving training on fuel consumption and are there interaction effects of training and incentives in inducing eco-driving?

These two research questions are answered through a two-stage natural field experiment conducted with different branches of a German logistics company. This thesis is thus one of very few approaches within energy and transport research to employ a controlled natural field experiment in the sense of Harrison and List (2004) to demonstrate causal relations (Metcalf & Dolan, 2012). In the first phase of the experiment, variable monetary and non-monetary rewards for eco-driving were introduced to a subset of drivers and a control group was maintained to test the incentives' efficacy over a six-month period. In the second phase of the experiment, the drivers participated in an eco-driving training while the incentive mechanisms continued for another six months. Individual drivers' fuel consumption was logged before and during the experiment, and additional individual information was collected anonymously from company records as well as a driver survey. To identify significant treatment effects, the resulting data was analyzed via assorted panel regression models.

The third research area of the thesis focuses on cognitive biases that perpetuate unsustainable practices and are both socially and environmentally dysfunctional (Hoffman & Bazerman, 2007). Overconfidence (i.e., the tendency of people to be excessively confident in their own knowledge, abilities, performance, and/or estimations) is arguably the most prevalent and robust judgment bias in human decision-making (De Bondt & Thaler, 1995; Glaser, Langer, & Weber, 2013). Overconfidence can be beneficial in specific situations, such as negotiations or recovering from a serious disease (Shapira-Ettinger & Shapira, 2008), but it is generally agreed to lead to suboptimal decisions in individuals' private lives and in their roles as investors, managers, or politicians (Glaser et al., 2013). In particular, research in different fields describes overconfidence as a threat to sustainability in financial decision-making and the financial system (Biais, Hilton, Mazurier, & Pouget, 2005; Clarkson, 2009; Dittrich, Güth, & Maciejovsky, 2005), decision-making under risk and uncertainty related to climate change (Bay, 2010; Marx

& Weber, 2012), energy demand forecasts (Morgan & Keith, 2008), decisions on energy policy (Hall, 2010), long-term futures decision-making (Tonn, 2003), and decision-making concerning energy saving, resource conservation, and emission reductions (Flemming et al., 2008; Rickards, Wiseman, & Kashima, 2014).

A considerable amount of research has focused on ways to decrease overconfidence in order to reduce unsustainable and suboptimal decision-making. Among the different measures examined, simply warning people of overconfidence has been deemed to be one of the least effective (Plous, 1995). Recent studies generally take this assessment for granted and leave it unchallenged; to support this, they almost exclusively refer to the early findings of Alpert and Raiffa (1982), Block and Harper (1991), and Fischhoff and Slovic (1980), which align with the view of Plous (1995). Research on projecting future energy use and CO₂ emissions similarly refers to Alpert and Raiffa (1982) to support the argument that training to improve calibration in estimating probability distributions is ineffective (Morgan & Keith, 2008). These studies only examine weak static warnings, but recent research on the provision of advice (Bonaccio & Dalal, 2006) and the de-biasing effect of strong warning messages regarding other cognitive biases (Cheng & Wu, 2010) indicates that the conventional wisdom regarding overconfidence warnings being ineffective might not always hold. This motivates the third research question:

(3) Do warnings that are enhanced and dynamic in terms of structure, content, and design significantly reduce overconfidence?

This thesis addresses this research question through two separate laboratory experiments in which participants must answer general knowledge questions with 90% confidence intervals for each question, a popular method that is often applied to elicit overconfidence in experimental approaches (Deaves, Luders, & Luo, 2009; Fellner & Krügel, 2012; Jain, Mukherjee, Bearden, & Gaba, 2013; Yaniv & Foster, 1997). Using such a well-tested laboratory experiment facilitates comparisons with previous studies' results and allows for systematic analysis of variations in the warning design within a controlled environment. Accordingly, both experiments employ a between-subjects design with a control condition (no warning of overconfidence) and include several treatments (i.e., different warnings for being potentially overconfident), with a focus on dynamic warnings in the second experiment. Research on human factors and ergonomics has led to great progress in

understanding and defining the use of warnings (see Rogers, Lamson, & Rousseau, 2000, Wogalter, 2006, and Wogalter & Conzola, 2002 for an overview) and can contribute significantly to sustainable development (Moore & Barnard, 2012; Sethumadhavan, 2014). As such, the different experimental warning treatments were developed based on these insights. To identify significant differences in the effects of the various warning treatments, one-way between-subjects analyses of variance and non-parametric Kruskal Wallis H-tests with appropriate post-hoc analysis of pairwise comparisons were applied, as were ordinary least squares and logit regressions.

Finally, drastically increasing the share of RE in the energy mix is a cornerstone of many countries' plans for transitioning to sustainable low-carbon economies (e.g., Leaders of the G7, 2015). Large investments in RE over the next decades are required to reach these goals (Bergek et al., 2013; Masini & Menichetti, 2012), and financial citizen participation plays an increasingly important role in raising sufficient capital to fund such RE projects (Yildiz, 2014; Yildiz et al., 2015). However, while research on socially responsible investment (SRI) has generally found that ethical and social factors can play important roles in the investment decision-making process (Escrig-Olmedo, Muñoz-Torres, & Fernández-Izquierdo, 2013; Nilsson, 2008; Scholtens & Sievänen, 2012; Williams, 2007), there is little understanding of which non-financial factors influence or interact with citizen-investors' decisions to invest in RE (Bergek et al., 2013; Masini & Menichetti, 2013; Mathews et al., 2010; Yildiz, 2014). Thus, the fourth research question is the following:

(4) Which individual sociodemographic and psychographic traits are associated with citizen-investors' decisions to invest in RE projects and which areas of society show the greatest potential for increasing the financial citizen participation?

This question is addressed through a survey-based investigation of the sociodemographic and psychographic characteristics that distinguish RE citizen-investors from their fellow citizens. Based on a simple conceptual model, items from the German Socio-Economic Panel (SOEP) questionnaire and a biannual survey of the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) and the German Federal Environment Agency (UBA) are deployed in a survey of private citizens who have invested in RE in Germany. Using representative data from the other two surveys as a

control and applying logistic regression and exploratory factor analysis, characteristic sociodemographic and psychographic traits of RE investors are identified and discussed.

This methodological approach has several advantages compared to previous studies and other methods, such as laboratory experiments. First, instead of relying on behavioral intentions, analyzing the characteristics of individuals who actually invested in one or more RE energy projects avoids the issue of inflated intentions, which has plagued many previous studies of SRI decision-making (Nilsson, 2008). Second, using representative data from large-scale surveys allows for a reliable comparison to the broader population.

1.3 Contribution and structure

This thesis makes contributions relevant to two main groups: (1) decision-makers in politics and industry and (2) researchers in behavioral sciences and sustainable development.

First, focusing on the increasingly recognized problem of unsustainable decision-making worldwide, this thesis examines the influence of non-financial elements on sustainable decision-making and possible measures to increase sustainable behavior. The approach questions the assumption of rational decision-makers, which remains overly prevalent in policy circles. This research can thus help political decision-makers identify suitable policy measures and design more effective ways to support sustainable development, not only in the environmental domain but also in other areas, such as the financial system. The results underline the growing influence of behavioral economics on public policy, which is necessary because an understanding of human decision-making that goes beyond rational choice models is required to develop and implement more effective policies to foster green growth and sustainability (Dolan et al., 2012; Dolan & Metcalfe, 2013; Weber & Johnson, 2012). Private actors can also draw on the thesis's results to develop tailored instruments to decrease energy costs, reduce unsustainable and biased decision-making, and increase RE investment.

Second, in response to the call for more interdisciplinary interaction and a social science research agenda (Minsch et al., 2012; Sovacool, 2014), this thesis advances research in behavioral economics and sustainable development in several aspects. On the one hand, it

helps fill identified research gaps, both in content and methods, by examining mostly non-financial drivers of sustainable behavior that have not been analyzed to date and applying methods that have rarely been applied in this area, such as controlled natural field experiments (Metcalfe & Dolan, 2012; Sovacool, 2014). On the other hand, it advances scientific knowledge of the cognitive mechanisms of decision-making relevant to sustainable development, such as habit and overconfidence, and complements research on how to best influence these mechanisms in order to facilitate more sustainable behavior.

This thesis answers the research questions presented above through separate empirical studies of monetary and non-monetary incentives for fuel-efficient driving (Chapter 2), the long-term persistence and potential interaction of the effects of incentives and training for fuel-efficient driving (Chapter 3), the effectiveness of warnings meant to reduce overconfidence (Chapter 4), and socio-psychological drivers of citizen-investors' decisions to invest in RE (Chapter 5). The insights of Chapter 4 are focused on the basic research level because the notion of analyzing different warning designs' effects on overconfidence is fundamentally new; this general insight can later be transferred to specific settings in which overconfidence hinders sustainable development. Chapters 2, 3, and 5 also take a more applied perspective. Since each section of the thesis represents a distinct scientific contribution on its own, the chapters are treated as independent studies with their own introductions, literature reviews, and methods sections. Chapter 6 then summarizes the main results of all of the studies and discusses their overall implications for practice and future research.

2 Incentives for energy-efficient behavior at the workplace: A natural field experiment on eco-driving in a company fleet²

Summary

Reducing greenhouse gas emissions is a highly prevalent goal of public policy in many countries around the world. Convincing people to drive more fuel-efficiently (“eco-driving”) can contribute substantially to this goal and is often an integral part of policy initiatives. However, there is a lack of scientific studies on the effects of individual monetary and non-monetary incentives for eco-driving, especially in organizational settings and with regards to demonstrating causality, e.g., by using controlled experiments. This gap is addressed with a six months long controlled natural field experiment. A monetary and a non-monetary reward for eco-driving are introduced to drivers of light commercial vehicles in different branches of a logistics company. The results show an average reduction of fuel consumption of 5% due to a tangible non-monetary reward and suggest only a small reduction of the average fuel consumption in the equivalent monetary reward treatment. Building on the extant research on psychological determinants of transport behavior and economic incentives, possible explanations for the observed behavior and the potential superiority of non-monetary rewards over pure money are presented. Finally, policy implications for private and public actors are discussed.

² This chapter is based on a working paper co-authored by Alwine Mohnen that has been accepted for publication in *Applied Energy* (DOI: 10.1016/j.apenergy.2015.10.163) since the submission of this dissertation. The full chapter is included in the examiners’ copies of this dissertation. In order to avoid any kind of plagiarism or dual publication it is not included in the freely accessible version of this dissertation. My contribution to the paper is summarized in the Appendix (signed by the authors in the examiners’ copies of this dissertation). A short summary version was published in *Energy Procedia* as part of the conference proceedings of the 7th International Conference on Applied Energy (2015), Abu Dhabi (see Schall & Mohnen, 2015).

3 Time-dependent effects and (non-)interactions of training and rewards for energy-efficient behavior: A natural field experiment on eco-driving in a company fleet³

Summary

Eco-driving is a cornerstone of policy initiatives for energy efficiency in the transportation sector. But there is a lack of studies on the long-term persistence and potential interaction of the effects of incentives and training on energy conservation behavior in general and eco-driving behavior in particular. The study addresses this gap with a twelve months long natural field experiment in three branches of a logistics company to analyze the time-dependent and potentially interacting effects of rewards and theoretical training for eco-driving on fuel consumption in a real-world setting. It finds an immediate reduction of fuel consumption following the introduction of a non-monetary reward and an attenuation of this effect over time. Theoretical eco-driving training shows no effect, neither short-term nor long-term, highlighting the often neglected necessity to include practical training elements. Contrary to common assumptions, the interaction of incentives and theoretical eco-driving training does not show an additional reduction effect. Taking the extant research on energy conservation behavior into account, the results underline the need for a careful selection and combination of interventions to achieve persistent effects. Policy implications for public and private actors are discussed.

³ This chapter is based on a working paper co-authored by Menas Wolf and Alwine Mohnen that is currently under review for publication. The full chapter is included in the examiners' copies of this dissertation. In order to avoid any kind of plagiarism or dual publication it is not included in the freely accessible version of this dissertation. My contribution to the paper is summarized in the Appendix (signed by the authors in the examiners' copies of this dissertation).

4 Warnings as a useless measure against unsustainable decision-making? An experimental evaluation of using warnings to reduce overconfidence⁴

Summary

People often display excessive overconfidence when providing interval estimates, which biases decision-making and perpetuates unsustainable practices. Research has investigated the various measures to effectively reduce overconfidence, and the use of warnings has subsequently been considered to have a negligible reduction effect. This study demonstrates with two separate experiments that the impact of warnings has to be reviewed in light of dynamic warning designs and cognitive warning process models. In experiment 1, in contrast to previous studies that only used unstructured warnings, a warning is implemented incorporating some core elements of a structured warning design based on research in the fields of human factors and ergonomics. Furthermore, accounting for recent developments in the warning literature, the study distinguishes between static and dynamic warning design. Experiment 2 examines the effectiveness of different elements of dynamic warnings. It shows that a significantly higher reduction of overconfidence can be achieved by combining a structured warning content with a dynamic stimulus change to increase the warning's noticeability.

⁴ This chapter is based on a working paper co-authored by Dominik Doll and Alwine Mohnen that got accepted for publication in the *Journal of Behavioral Decision Making* (DOI: 10.1002/bdm.1946) after the submission of this dissertation. The full chapter is included in the examiners' copies of this dissertation. In order to avoid any kind of plagiarism or dual publication it is not included in the freely accessible version of this dissertation. My contribution to the paper is summarized in the Appendix (signed by the authors in the examiners' copies of this dissertation).

5 More than money? An empirical investigation of socio-psychological drivers of financial citizen participation in the German energy transition⁵

Summary

To reach the ambitious targets of many countries' plans for an energy transition, large investments in renewable energy are needed. While financial citizen participation plays an increasing role in securing the required investments, there is a lack of understanding which socio-psychological factors influence or interact with a citizen's decision to invest privately in renewable energy. Based on a conceptual model derived from the extant research and own interviews, a survey among citizen investors of renewable energy projects in Germany is conducted and compared to representative data from existing population samples using logistic regressions. The results indicate that the typical citizen investor is more likely to be male with a higher (household) income, to have a higher education, and to live in a more rural area compared with the rest of the population. In addition, the typical investor exhibits strong proenvironmental beliefs and behaviors as well as a predisposition for active citizenship. Furthermore, feeling well-informed and getting a non-financial or "psychic" return from the investment seems to be important for the decision. Strategic adaptations for public and private actors are suggested to increase financial citizen participation.

⁵ This chapter is based on a working paper (single-authored) that is currently under review for publication. The full chapter is included in the examiners' copies of this dissertation. In order to avoid any kind of plagiarism or dual publication it is not included in the freely accessible version of this dissertation.

6 Conclusion

6.1 Summary of main results

Examining the advantages of non-monetary incentives for fuel-efficient driving (Chapter 2), the long-term persistence and potential interaction of the effects of incentives and training for fuel-efficient driving (Chapter 3), the effectiveness of different warnings meant to reduce overconfidence (Chapter 4), and socio-psychological drivers of citizen-investors' decisions to invest in RE (Chapter 5), this thesis aimed to advance knowledge of how behavioral science insights can facilitate sustainable development. The main results of Chapters 2 to 5 can be summarized as follows.

Chapter 2 represented the first study to systematically analyze and compare a monetary and a non-monetary incentive for workplace-based energy-efficient behavior (here, eco-driving) using a natural field experiment, which was done across several branches of a logistics company. The results showed a reduction in average fuel consumption following the introduction of incentives. On average there was a significant 5% reduction in fuel consumption due to the tangible non-monetary incentive and a 3.5% average reduction in the equivalent monetary incentive treatment, though this was insignificant.

Result 1: *Individual incentives for drivers can increase fuel-efficiency by up to 5% and, contrary to rational economic theory, non-monetary incentives can have a larger effect on drivers' fuel consumption than equivalent monetary incentives.*

Considering this result as well as insights from previous studies on the role of habits in transport behavior, it can be concluded that the non-monetary aspects of an incentive are more important than the monetary value when aiming to interrupt habitual car use and facilitate a deliberate choice of more eco-friendly driving and thus lower fuel consumption and greenhouse gas emissions. This study indicates that greater emphasis on the enjoyable aspects of achieving higher fuel efficiency, a more emotional response to non-monetary incentives, and a more frequent thinking and talking about non-monetary incentives might

help drive the stronger effect of tangible non-monetary incentives in comparison to an equivalent monetary incentive.

Building on the results of Chapter 2, Chapter 3 focused on the second phase of the field experiment to examine the potential existence and persistence of the effects of economic incentives and theoretical eco-driving training on fuel consumption; whether the effects interact was also considered. In line with research on the effects of incentives for lifestyle changes and other energy conservation interventions, after the immediate reduction in fuel consumption following the introduction of a non-monetary reward, as described in Chapter 2, the effect was found to fade after six months. In addition (and in contrast to a very broad and common assumption about the efficacy of eco-driving training), purely theoretical eco-driving training had no short- or long-term effect on fuel consumption. Also contrary to common assumptions in research on proenvironmental behavior, the interaction of economic incentives and theoretical eco-driving training had no additional effect on fuel consumption. The results of the different regression models were mixed but partially even indicated a counterproductive interaction effect. This may have been the result of either the sequential (instead of parallel) implementation of the two interventions or the strong extrinsic influence of the combination of two interventions on drivers' perceived control over and competence at driving, leading to crowding out.

Result 2: *The effect of individual incentives for fuel-efficient driving on drivers' fuel consumption attenuates over time and is not reinforced by being paired with theoretical eco-driving training.*

Result 3: *Contrary to common assumptions and recommendations, purely theoretical eco-driving training has no effect on drivers' short- or long-term fuel consumption.*

Although effective in the short term, the economic incentives for eco-driving used in the field experiment do not seem to be able to disrupt drivers' long-engrained habits in the long run. This decreasing effect of the non-monetary incentive over time may be due to a change in the reference point after the first phase of the field experiment. Alternatively, there may be a demotivating effect of the individual comparison between the actual incentive outcome after the first six months and the driver's initial expectations (i.e., his/her initial reference point). However, there were no signs that economic incentives had

an overall counterproductive effect for eco-driving over the full course of the experiment. Thus, despite the observed lack of long-term persistence without additional measures, introducing economic incentives for eco-driving seems to be beneficial.

Chapter 4 challenged the conventional wisdom that warnings do not reduce overconfidence, arguing that the weak static warnings tested in prior research were not chosen so as to maximize their effectiveness. Using two laboratory experiments with a between-subjects design to elicit interval estimates for general knowledge questions, the effectiveness of enhanced and dynamic warnings based on insights from research in human factors and ergonomics was tested. The results of the first experiment showed that a warning's effectiveness in reducing overconfidence depends largely on its design but cannot be broadly neglected.

Result 4: *While enhanced static warnings have no effect on the level of exhibited overconfidence, a dynamic warning can result in a substantial reduction in overconfidence and thus facilitate more sustainable decision-making.*

Neither weak nor enhanced static warnings proved strong enough to affect information processing or the mapping of individual confidence to the response scale (and thus overconfidence levels). Conversely, a significant reduction in overconfidence was achieved by implementing dynamic warnings. Considering the effectiveness of different elements of dynamic warnings, the results of the second experiment suggested that a warning must contain appropriate content and be presented in a dynamic fashion in order to significantly reduce overconfidence.

Result 5: *A significant reduction in overconfidence can be achieved by combining structured warning content with a dynamic stimulus change that increases the warning's noticeability, such as a pop-up window.*

Recipients of dynamic warnings show higher rates of recall for warning content; this indicates greater warning noticeability due to the stimulus change, which, following the warning process model, might ultimately lead to greater warning compliance. In addition, participants give more inclusive estimates (i.e., significantly wider intervals) when confronted with a dynamic warning. This might result at least partly from participants

changing their mapping of feelings of confidence to the required response scale due to the strong warning.

Chapter 5 empirically examined which individual characteristics differentiate private RE investors from the rest of the population. This was done to identify the socio-psychological factors that are important in proenvironmental investment decisions in general and RE investment decisions in particular. Based on a simple conceptual model and hypotheses derived from research on SRI and the Value-Belief-Norm Theory, data on citizen-investors in RE projects in Germany was collected via a survey and compared to representative population data using logistic regressions and factor analysis. The results indicated that several sociodemographic and psychographic variables are positively associated with citizen investment in RE.

Result 6: *From a sociodemographic perspective, the typical German RE citizen-investor is more likely than the rest of the population to be male, have a higher (household) income, have completed higher education, and live in a more rural area.*

Result 7: *Psychographically, the typical investor exhibits strong proenvironmental beliefs and behaviors as well as a predisposition towards active citizenship. Being knowledgeable about the project and attaining a positive feeling (i.e., some form of non-financial or “psychic” return on the investment) seem to help drive the decision to privately invest in RE.*

Overall, the results strongly suggest that socio-psychological variables play a major role in the decision to invest in RE. Despite the characterization of the current typical RE citizen-investor, the results indicate untapped potential in other potentially receptive population segments, such as women (who generally have a high affinity for SRI), lower-income and less-educated people (e.g., through low minimum investment amounts and simple products, respectively), and young urbanites (who are generally highly ecologically aware and might be susceptible to certain RE investment framings). Overall, it is important to ensure RE investments are environmentally framed and to communicate them as an option that embodies a lifestyle of proenvironmental behavior and personal engagement as opposed to a way to balance a hedonistic lifestyle.

6.2 Implications for practice and future research

There are always limitations to the generalizability of specific results with respect to cultural, contextual, and other circumstances. However, the results of this thesis have several important implications for practice and future research.

First, in contrast to rational economic theory, people were shown here to prefer non-monetary rewards for saving energy over monetary rewards in certain situations, be prone to judgment biases (such as overconfidence, which can be reduced with dynamic warnings), and be influenced by non-financial, socio-psychological factors when making RE investment decisions. Thus, policymakers and private sector actors should set aside the notion of a perfectly rational human decision-maker and incorporate behavioral scientific insights when devising and implementing measures to facilitate sustainable development and eco-friendly decision-making. Such interventions should take into account the motivational power of non-monetary components of rewards. Efforts to strengthen public support for RE and to market RE investment opportunities should keep in mind the characteristics and needs of the currently prevalent type of investor. At the same time, they must put more effort into reaching underrepresented but potentially receptive segments of society by tailoring approaches to specific socio-psychological profiles.

Second, despite many studies of proenvironmental behavior characterizing, often without empirical foundation, a combination of different interventions (i.e., a multi-measure approach) as a “magic bullet” to increase proenvironmental behavior, effects will not appear automatically. In particular, combining economic incentives and informational approaches to increase proenvironmental behavior sometimes works but does not seem to be effective for increasing eco-driving, at least when practical training elements are not included.

Third, sustainably influencing decision processes or actions in which habit and habituation play a strong role (e.g., energy consumption behavior and other everyday actions that influence the environment) requires robust and strong behavioral measures. Future research, especially field experiments, should thus focus more on approaches with the potential to disrupt habitual behavior and facilitate deliberate choice of behavior. Moreover, additional research is needed to further differentiate between influential and

irrelevant elements of warning messages and to refine the simple conceptual model of non-financial influences on RE investment decisions. Confirming the results regarding non-financial drivers of RE investment decisions using a larger and integrated sample as well as different methodological approaches, such as laboratory experiments or case studies, would further validate the results and implications presented here.

Overall, this doctoral thesis added important insights, with implications for all actors that seek to support and expand sustainable development. It complements increasing efforts to raise awareness among both practitioners and researchers of biases in decision-making, potential remedies, and non-monetary drivers of behavior. Approaches that are cognizant of these nuances can better reinforce resource conservation and sustainable decision-making.

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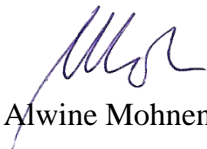
Appendix: Contribution to working papers

Working paper 1 (Chapter 2)

I was responsible for the development of the research questions and the design of the experiment. I planned and supervised the execution of the field experiment, conducted the data analysis largely independently, and wrote the most part of the article.



Dominik Schall (lead author)



Alwine Mohnen (co-author)

Working paper 2 (Chapter 3)


I was responsible for the development of the research questions and the design of the experiment. I planned and supervised the execution of the field experiment, conducted a significant part of the data analysis, and wrote the most part of the article.



Dominik Schall (lead author)



Menas Wolf (co-author)



Alwine Mohnen (co-author)

Working paper 3 (Chapter 4)

I developed the core research question and a significant part of the design of the experiment. I was in charge for some of the experimental sessions in the laboratory, conducted most of the data analysis, and wrote large parts of the article.



Dominik Schall (lead author)



Dominik Doll (co-author)



Alwine Mohnen (co-author)