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DISCUSSION PAPER

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The Demand for Voluntary Carbon Dioxide Removal – Experimental Evidence From an Afforestation Project in Germany

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Comprehensive mitigation efforts (including all emission sources and sinks, all GHGs, and all economic sectors) are becoming ever-more important. While established methods of direct emissions avoidance must continue to form the basis for climate mitigation strategies, increasing attention is being paid to carbon dioxide removal (CDR) technologies as a supplementary tool to counterbalance hard-to-abate residual emissions. In this paper, we focus on the individual level perspective. In a framed field experiment, we examine individual willingness to pay (WTP) for carbon removal through afforestation on a German sample. We focus on the role played by the local co-benefits of climate protection activities, and add geo-data to our experimental data to analyze the impact of variation in individual geographic location on WTP. Our results indicate that WTP for carbon removal exceeds the WTP for emissions avoidance estimated by previous experimental studies. We do not find evidence that emphasizing co-benefits increases WTP for carbon removal more than would be expected. We conjecture that this result may stem from the non-observed beliefs and priors of the subjects. Additional survey data find that trust in forest measures is higher than mitigation through an emissions trading scheme, which could explain the comparably high WTP.

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1. Introduction

With governments around the world committing to reach net zero greenhouse gas (GHG) emissions by the middle of the century, comprehensive mitigation efforts (including all emission sources and sinks, all GHGs, and all economic sectors) are becoming increasingly important (Honegger et al. 2021). CO_2 emission avoidance focuses on emission sources, and seeks to reduce emissions by harnessing low-carbon technologies, developing renewable energy systems, and improving energy efficiency (Fawzy et al. 2020). Because avoidance efforts are directed towards the source of emissions, they have the advantage to also avoid all potential local co-losses. These established methods of direct emissions avoidance must continue to form the basis for climate mitigation strategies. However, there is growing consensus that avoidance alone will not suffice to reach the Paris climate goals (Fekete et al. 2021; Lawrence et al. 2018; Nieto et al. 2018). Attention is therefore increasingly being paid to carbon dioxide removal (CDR) technologies as a supplementary tool to counterbalance hard-to-abate residual emissions.

In this paper, we focus on the individual level perspective to better understand how subjects are willing to help reduce residual emissions via direct individual voluntary contributions. After taking action to reduce their carbon footprint, individuals have various options for lowering emissions. They can purchase and withdraw emissions allowances from existing emissions trading schemes (ETS; e.g. through compensators.org), which implies that another economic actor gives up a right to pollute. In addition, they can offset residual emissions through voluntary contributions to CDR projects. We focus on this second case, and conduct a framed field experiment on a sample of the German population, using a revealed preference approach to estimate individual willingness to pay (WTP) for carbon sequestration through afforestation.

CDR[1] lowers atmospheric CO_2 concentrations by removing CO_2 from the atmosphere and sequestering it in geological, terrestrial, or ocean reservoirs (Herzog and Golomb 2004). In addition to continuing and enhancing emission avoidance as the dominant mitigation strategy, CDR represents an important tool for reaching net zero and counterbalancing residual emissions. CDR is an element of all IPCC scenarios that limit global warming to 2°C (IPCC 2022; Smith et al. 2023). Currently, afforestation/reforestation, as well as the management of existing forests, account for about 99% of deployed CDR land measures (Smith 2023).[2] Establishing forest carbon sinks, e.g. through

[1] For a comprehensive overview of CDR literature and the potentials, costs, and implications of deployment, see Fuss et al. (2018) and IPCC (2022).

[2] Other CDR measures such as Bioenergy with Carbon Capture and Storage (BECCS), Direct Air Carbon Capture and Storage (DACCS), biochar, and enhanced rock weathering are expected to be implemented on a large scale over the course of the century (Smith 2023).

afforestation or reforestation,[3] are among the few measures for which large-scale CDR may be possible at present (IPCC 2022).

Forest carbon sinks are considered to have a large potential to support climate stabilization (Austin et al. 2020; Cook-Patton et al. 2020; Forster et al. 2021; Lewis et al. 2019) and to decrease peak warming over the short- to mid-term (Matthews et al. 2022). A strand in the literature stresses their low-cost potential: the marginal cost of establishing carbon sinks can be lower than that of emissions avoidance (Gren and Aklilu 2016; Richards and Stokes 2004; van Kooten et al. 2004; van Kooten 2017). Cost calculations vary considerably, however. According to a meta-regression analysis by van Kooten et al. (2004), the costs of forest carbon sequestration vary between \$12.7 and 70.9/tCO_2. This is explained by varying model assumptions, e.g. about the rate of carbon uptake, previous land usage, the risks of natural disturbances, and the considered time span (Bateman and Lovett 2000; Canadell and Raupach 2008; Ninan and Inoue 2013; Núñez et al. 2006; van der Horst 2006). Carbon uptake again crucially depends on various factors, including the tree species in question (e.g. indigenous vs. non-indigenous, diversity), tree growth and carbon sequestration rates, the climate zone, land suitability, harvest times, and management (Bastin et al. 2019; Matthews et al. 2022; Neumann et al. 2016; Newell and Stavins 2000; Obersteiner et al. 2018; Pires 2019). In addition, most studies fail to adequately take into account the ongoing costs of maintenance to assure that the expected carbon sequestration is realized. When the opportunity costs of land use[4] are taken into account, the average costs rise significantly (van Kooten et al. 2004).

Nonetheless, establishing forest carbon sinks has been garnering increased political and public attention. Forest carbon sinks were a subject of keen discussion at COP27 or within the EU Forest Strategy for 2030, which commits EU member states to reverse forest loss and pledged to increase forest coverage. However, the integration of forest carbon sinks as a tool of climate policy requires a better understanding of how markets value carbon sinks, associated demand-side responses, interactions with emission avoidance measures, and potential benefits and trade-offs (Holl and Brancalion 2020; Shrestha et al. 2021). To be sure, forest measures are no panacea in the fight against climate change. Increasing the tree coverage of land is complex and estimates of mitigation potential still fail to account for potential synergies or trade-offs with other ecosystem services (ES), such those arising from biodiversity (Burton et al. 2018; Hardaker et al. 2021; Matthews et al. 2022; Plantinga and Wu 2003).

[3] Climate change mitigation scenarios typically make no differentiation between reforestation and afforestation despite the measures' different overall environmental impacts (IPCC 2019). We focus on afforestation, which converts non-forest land (e.g. agricultural land or brownfields) to forest land. Reforestation describes the replanting of trees in existing forests that are depleted or destroyed.

[4] Research on the relationship between land use change and ES is increasing and has revealed complex synergies as well as trade-offs (Lautenbach et al. 2017). Large-scale afforestation can, for example, severely impact biodiversity, albedo, hydrology, nutrient use, food security, as well as land competition – with impacts being context and scale specific (IPBES 2019; Smith et al. 2019). In the scope of this paper it is not possible to explore and discuss these trade-offs and synergies. Burton et al. (2018) provide a systematic review of how woodland expansion impacts biodiversity and other ES and identifies the main knowledge gaps.

In addition, forest measures have a "permanence problem." The long-term carbon-storage capacity of forests is uncertain, as carbon sequestration is reversible, e.g. through deforestation or natural disturbances (Maréchal and Hecq 2006).

We conduct an incentivized framed field experiment, in which we ask participants to give up real money to support a local afforestation project and thus remove CO_2. From an economic point of view, analyzing willingness to pay (WTP) for afforestation provides an interesting source of experimental variation to elicit the role of "co-benefits" in voluntary mitigation efforts. This is inspired by the idea that an active communication of co-benefits can encourage additional mitigation activities (Bain et al. 2016; Longo et al. 2012; MacKerron et al. 2009; Torres et al. 2015). Co-benefits describe the positive side effects mitigation actions have on other dimensions beyond climate change (IPCC 2022). While the primary public good component (i.e. the benefits of removed GHG emissions) is global in scale, most co-benefits accrue in a predominantly local context. This is particularly true for forest co-benefits,[5] such as recreational opportunities, air quality improvements, improved natural regulation of atmospheric temperature, and improved biodiversity, all of which are highly palpable.

In addition, we know from ecosystem service studies that the (stated) valuation of goods and services is subject to a distance-decay function: with increasing distance from the site that provides ES, WTP tends to decline (Bakhtiari et al. 2018; Bateman et al. 2006; Del Saz Salazar and García Menéndez 2007; Schaafsma et al. 2013). Similarly, local benefits are expected to correlate with spatial distance (Abildtrup et al. 2013; Schaafsma et al. 2013; Torres et al. 2015). To account for this, we consider the geographical position of each subject. This allows us to construct a distance measure through which we can i) investigate the distance-decay effect and ii) add geo-data (e.g. forest coverage, urbanization level) to our data, thus allowing us to analyze the impact of spatial variation on individual WTP.

Our results suggest that WTP for carbon removal exceeds the WTP for emission avoidance efforts found in previous experimental studies. We do not find evidence that emphasizing co-benefits increases WTP for carbon removal. We conjecture that this result may stem from the non-observed beliefs and priors of the subjects. When subjects are already aware of co-benefits, stressing them may not have an additional effect. To test this conjecture, we conducted an additional survey among a new sample consisting of individuals who had not taken part in first experiment. This survey sought to investigate existing knowledge regarding forest carbon sinks and their benefits in Germany.

We contribute to three strands of the literature. First, our experimental design strongly relates to research investigating WTP for CO_2 mitigation. Previous studies typically evaluate WTP for emission avoidance, e.g. purchasing and withdrawing emissions allowances from existing ETSs. Revealed preference studies with incentive compatible settings find a low but positive willingness to voluntarily

[5] Forests provide ES that are categorized in terms of use and non-use values (Bateman and Lovett 2000; Canadell and Raupach 2008; Ninan and Inoue 2013; Núñez et al. 2006; van der Horst 2006). Local co-benefits accrue especially in term of use values such as recreation, education, tourism, timber, biodiversity, carbon storage, improved air quality, soil protection, and hydrologic functions. Non-use values include the bequest value, altruist value, and existence value.

pay for emission avoidance – e.g. the majority of reported median WTP values is €0/tCO_2 (Diederich and Goeschl 2014; Löschel et al. 2013; Löschel et al. 2021). These findings contrast with evidence from stated-preference approaches, which usually show a positive WTP for climate protection (Achtnicht 2012; MacKerron et al. 2009; Uehleke and Sturm 2017). This research strand has focused thus far on WTP for emissions avoidance.

Second, we contribute to the research on the co-benefits of climate mitigation. Most research on co-benefits has been done in the context of emission avoidance through the retirement of allowances from an existing ETS, using both stated and revealed preference methods (Feldhaus et al. 2022; Longo et al. 2012; Löschel et al. 2021; MacKerron et al. 2009). However, allowance retirements and afforestation differ in terms of the prominence of their co-benefits. In the context of carbon removal, evidence is rather scarce and stems mostly from stated preference methods (Baranzini et al. 2018; Rodríguez-Entrena et al. 2014; Torres et al. 2015). Our experimental variation allows us to elicit the impact of highlighting co-benefits on the revealed WTP for forest carbon sequestration.

Third, our research is linked to the literature on forest ES, including their valuation and interrelationships with land-use choices and resulting consequences for ESs (see e.g. the meta-analysis by Taye et al. 2021). Forests provide significant use and non-use ES ecosystem services. Many of these services are provided indirectly. Consequently, the market prices of forest goods often fail to take forest ecosystems services into account (Taye et al. 2021). In our view, this is particularly true for the value of forests as carbon sinks. With the shift toward actively integrating forest carbon sinks into climate policies, there is a need to develop a comprehensive understanding of public preferences in this regard. This includes the need to understand how individuals' value co-benefits that take the form of indirect use values. Shedding light on this issue can help policymakers to "design financial incentives […] that target the conservation of forests to preserve the otherwise non-marketed ecosystem services that they provide" (Taye et al. 2021, p.2). In this way, there is a demand for research that examines public perceptions of and potential support for related environmental interventions, including the feasibility of (large-scale) carbon removal, associated socioecological contexts, and potential trade-offs (Buck 2016; Wenger et al. 2021). Against this backdrop, there is also a need to cultivate appreciation for the socioeconomic value of forests as a non-permanent carbon removal option and contributor to lower peak emissions in the short- to mid-term. In this vein, our paper adds to the a growing literature on the public's perception and acceptability of natural CDR methods ((Bellamy 2022; Cox et al. 2020; Merk et al. 2023; Wolske et al. 2019) in general, and – more precisely – the literature on the valuation of carbon sequestration through forestry activities (Brey et al. 2007; Mogas et al. 2009; Rodríguez-Entrena et al. 2012; Rodríguez-Entrena et al. 2014; Shrestha and Alavalapati 2004; Tolunay and Başsüllü 2015; Torres et al. 2015). However, public perceptions regarding the value of forestry-based carbon removal, including associated demand-side reactions, has received very little attention in field experiments that elicit revealed preferences. A study by Baranzini et al. (2018) constitutes an exception, as it experimentally investigates voluntary contributions to a reforestation project to offset carbon emissions but in the lab using a student sample.

Consequently, experimentally assessing revealed preferences for carbon sequestration via local carbon forest sinks in a broader population sample remains a crucial gap in the literature. Moreover, it remains unclear to what extent insights from experimental studies on emission avoidance can be carried over to carbon removal scenarios given the different characteristics of public goods, especially the potentially higher impact of local co-benefits. Thus, the contribution made by our paper is to provide a first incentivized framed field experiment to elicit revealed WTP for forestry-based carbon removal in a broader population sample in light of the co-benefits this removal provides.

2. Methods

2.1 Framed Field Experiment

Our framed field experiment was conducted between 16 and 25 March 2020. It was attached to an online survey that was conducted jointly with the University of Münster and a German online price comparison website[6] that allows customers to compare the electricity service plans offered by different providers. Personalized survey invitations were sent via email to the platform's registered users, who stem from the general population. The invitation included information on the purpose of the survey and the time required to complete it. It also explained that participants would receive a fixed payment of €20 for completion, as well as an additional variable payment between €6 and €40, depending on their answers to the survey. The final payment was paid out through a voucher redeemable at over 500 stores. The survey was thematically unrelated to our experiment and investigated consumer behavior in the retail electricity market. Our experiment was placed at the very end of this survey. Participants were not aware of the actual experiment, in which we scrutinized their propensity to contribute to environmental protection under two different treatments.

In our survey design, we introduced a donation option as an experimental variation on the conventional financial reward for participating in a survey. Due to our design, we were unable to collect post-experimental data, e.g. on individual beliefs and motivations. Rather, we were only able to collect standard economic preferences[7] in addition to the age, gender, and geographical location of each participant. We acknowledge that the subjects' location during survey participation was not necessarily identical to their place of residence. However, the survey took place at the beginning of the German COVID lockdowns. Childcare facilities and schools were closed; remote work was encouraged; and public life was reduced. These factors increased the chance that participants were located at home.

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[6] See Appendix A.2 for a detailed description of the sampling procedure and information on the electricity platform.

[7] The questions relate to the Global Preference Survey (Falk et al. 2016; Falk et al. 2018) and the Need for Cognition Scale (NFC-K) (Beißert et al. 2014).

After subjects completed the survey, we informed them that they could support an afforestation project by making a donation from the fixed share[8] of their payment for participating. To implement a real donation, we collaborated with the City of Mannheim, which is hosting the National Garden Show[9] in 2023. For the event, a disused military base is being transformed into green areas, and approximately 1,000 trees will be planted, thus creating an additional local carbon sink. Subjects were asked how much they would be willing to donate to the afforestation project, given 100 kg of CO_2 removal from the atmosphere.[10]

We also introduced a treatment that addressed co-benefits. The survey program randomly divided subjects into two groups: namely, the sink (*S*) and the co-benefit (*CBS*) treatments. In both treatments, subjects received relevant information on the need for global climate protection. This ensured that each participant had the same basic knowledge regarding climate change and the role played by trees in climate-change mitigation efforts. In particular, we explained the role of forest carbon sinks in climate protection, and gave subjects information on the average CO_2 absorption capacities of trees using the example of a beech tree, which, on average, absorbs 100 kg of CO_2 over eight years (Klein 2009). To make this information more accessible, we explained that 100 kg of CO_2 is approximately equal the emissions caused by a 550 km car trip. Finally, we gave subjects information on the local afforestation project, and explained their donation would be used to plant additional trees. In the *CBS*-treatment, by contrast, we additionally included information on local co-benefits. Specifically, we highlighted the project's advantages in terms of recreational opportunities, improved local air quality, the regulation of local atmospheric temperature, and greater biodiversity (see Appendix A.3 and A.4 for an overview and detailed information). Only after receiving this information were subjects asked to indicate their WTP. The likelihood of making a donation (extensive margin effect) and the amount donated (intensive margin effect) were the main outcome variables for our analysis.

2.2 Observational Data on Location

The attitude shown by participants towards the afforestation project may be affected by the distance-decay effect and the subjects' geographic locations (e.g. existing local forest coverage, level of urbanization). Past research has shown that WTP is affected by the accessibility of substitutes (e.g. other forested areas); Czajkowski et al. (2017), for example, find that WTP is higher when surrounding forests are scarce. To control for this, we match our experimental data with geo-data from the INKAR

[8] At this stage of the survey, participants did not know how much of the additional payment they would receive. Consequently, we only gave them the opportunity to donate their fixed reimbursement, which was the same for all participants.

[9] The German National Garden Show is a horticultural exhibition that enjoys great popularity: the last show attracted 1.5 million visitors. It takes place every two years in a different city, and lasts for six months.

[10] The selected volume of CO_2 is identical to the amount offered to participants in related studies, e.g. Löschel et al. (2017). The maximum WTP in our settings was equal to the individual's fixed remuneration. The maximum amount was rarely donated by participants, perhaps because it would have resulted in a very high WTP of 2,000 euros/tCO_2.

database (BBSR Bonn 2020) maintained by the German Federal Office for Building and Regional Planning. Most indicators have been collected on a continuous basis since 1995 and are granular to the district level. For our analysis, we draw on indicators of forest coverage, installed wind energy capacity, volume of recreational and agricultural space, urbanization level, and habitat density.

3. Literature and Hypotheses

As the individual costs that accrue from conservation efforts typically outweigh the individual benefits that can be expected to arise from increased environmental quality, strong free-riding incentives are expected to prevent contributions to global public goods such as GHG mitigation. However, vast experimental evidence demonstrates that individuals do contribute privately to public goods (see e.g. Ledyard 1995 and Chaudhuri 2011 for comprehensive literature reviews). This finding has been confirmed in studies estimating WTP for emission avoidance. In such studies, subjects are asked whether and/or how much they would pay to prevent emissions, based on the purchase and withdrawal of emission allowances from an emissions trading scheme (ETS), either using stated preference or revealed preference methods (Achtnicht 2012; Diederich and Goeschl 2014; Löschel et al. 2013; Löschel et al. 2021; MacKerron et al. 2009; Uehleke and Sturm 2017). With the increasing recognition that establishing forest carbon sinks is a promising supplementary path in climate change mitigation efforts, it is important to understand how market participants' value carbon sinks as a climate action measure, particularly in light of the unique characteristics of public goods. So far, it remains an open question as to whether the empirical insights developed regarding individual emission avoidance can be carried over to situations in which subjects can contribute to CO_2 removal.

Insights from stated preference studies show that individuals do inhibit a positive WTP for carbon removal via forests. Brey et al. (2007) use a choice experiment (CE) to elicit a valuation for an afforestation program in Catalonia, Spain. In terms of carbon sequestered, they find a WTP of €$1.74*10^{-4}$/tCO_2 per year. Rodríguez-Entrena et al. (2012; 2014) use data from the same CE and report a weighted individual WTP of €$4.28*10^{-6}$/tCO_2 per year for carbon sequestration through olive groves in Andalusia, Spain. Torres et al. (2015) use a CE to estimate the WTP for carbon sequestration through an afforestation project in Mexico. They report mean WTPs for four cities ranging between €5.57 and €11.39/tCO_2. Tolunay and Başsüllü (2015) use the contingent valuation method (CVM) to measure the WTP for the carbon sequestration service of forests in Turkey. They find a WTP of €0.07/tCO_2. To the best of our knowledge, Baranzini et al. (2018) is the only revealed preference study that investigates voluntary contributions to a reforestation project to offset carbon emissions in a lab setting based on a student sample. They report that, on average, participants contributed about 80% (6 CHF, approx. 6 euros) of their average endowment (7 CHF, approx. 7 euros).

Considering the lack of revealed preferences studies on WTP for carbon removal and the well-reported difference between stated and revealed WTP estimates for emission avoidance, we base our first hypothesis on the standard assumptions regarding the voluntary provision of public goods. Our first statistical hypothesis on WTP to contribute to carbon removal in the S treatment (WTP_S) thus reads as follows:

Hypothesis H1 $\quad H_0: WTP_S = 0 \quad H_A: WTP_S > 0$

Recent research suggests that co-benefits can play an important role in voluntary emission avoidance. Communicating these benefits can encourage mitigation activities (Bain et al. 2016). Past studies have generally focused on emission avoidance through allowance retirements, eliciting either stated or revealed preferences. Using a revealed preference approach, Löschel et al. (2021) and Feldhaus et al. (2022) find that co-benefits have a positive and significant effect on individual contributions to climate change mitigation. Diederich and Goeschl (2018) find the highlighting of co-benefits has no effect. However, it must be noted that in their setting, the co-benefits arise in connection with an emission avoidance project in a developing country. In this way, the co-benefits do not accrue directly to the experimental subjects, but rather to a distant population. Similarly, MacKerron et al. (2009) find a substantially higher (albeit hypothetical) WTP for carbon-offsetting projects that include co-benefits. Longo et al. (2012) find that stated WTP estimates to support climate change mitigation policies are higher when co-benefits are considered. This preference for co-benefits is also reflected in the voluntary carbon market. The Forest Trends' Ecosystem Marketplace report (2022) finds that carbon credits offered within projects that provide additional co-benefits enjoy a price premium.

While research on the economic valuation of the additional goods and services provided by forest ecosystems has grown exponentially,[11] studies estimating the impact of co-benefits on WTP for carbon removal are rare. A stated preference study by Tolunay and Başsüllü (2015) finds that respondents who attach importance to the co-benefits of forest ecosystems are willing to pay more for the forest. Torres et al. (2015) find that their participants are willing to pay higher carbon prices for carbon sequestration in nearby forests, thus reflecting the valuation of local co-benefits. Rodríguez-Entrena et al. (2014) find that WTP is higher in areas and for individuals who would directly benefit from a soil management program. Similarly, Baranzini et al. (2018) find that highlighting local benefits increases support for a domestic reforestation program.

However, the extent to which emphasizing the co-benefits of afforestation affect revealed WTP remains an open question. We expect contributions to be higher when the local benefits of afforestation are stressed compared to a setting in which they are not stressed (i.e. $WTP_{CBS} > WTP_S$). However, the provision of these local public goods (e.g. improved local air quality, higher biodiversity) may trigger additional free-riding behavior. If and how subjects react to information stressing local co-benefits thus remains an open question. Accordingly, we formulate our second hypothesis (H2) as follows:

[11] This research applies different valuation techniques (for an overview of methods, see Freeman 2003) across various categories (conservation type, forest type, type of ecosystem). Meta-studies (Barrio and Loureiro 2010; Mengist and Soromessa 2019; Taye et al. 2021) provide a comprehensive picture of how forest services are valued.

Hypothesis H2 H_0: $WTP_{CBS} = WTP_S$ H_A: $WTP_{CBS} > WTP_S$

While the primary public good component (i.e. the benefits of reduced GHG emissions) is global in scale, most of the co-benefits accrue in a local context, thus highlighting the importance of geographical distance from a project site. From ES studies we know that the (stated) valuation of goods and services is subject to a distance-decay function (Bakhtiari et al. 2018; Bateman et al. 2006; Del Saz Salazar and García Menéndez 2007; Schaafsma et al. 2013). This has also been reported for forest ecosystems (Abildtrup et al. 2013; Brouwer et al. 2010; Schaafsma et al. 2013; Torres et al. 2015). Specifically, subjects living within a close distance to a forest project are more likely to benefit from the local co-benefits that stem from the use values of a forest ecosystem. With increasing distance, the likelihood that the individual will use or profit from co-benefits decreases, thus affecting WTP. The literature also reports a negative relationship between non-use values and distance, which is predominantly driven by a social-distance mechanism. People have a higher WTP when they can personally identify with or feel connected to a given project or program (Jones and Rachlin 2006; Strombach et al. 2014). A similar relationship is found for WTP for emission avoidance: domestic offsetting options are often preferred over international ones (Anderson and Bernauer 2016; Buntaine and Prather 2018; Diederich and Goeschl 2018), a tendency that is predominately driven by preferences for local co-benefits (Löschel et al. 2021).

By emphasizing local co-benefits, the advantageous but locally bounded components of a project become more apparent to subjects. In this way, we expect an interaction between distance and our *CBS* treatment. If local favoritism holds in our setting, given the geographical dispersion of subjects, we can anticipate a difference between those who are located close to the afforestation project and those who are located further away. If this holds true, we can reject the null hypothesis (H_0: $\rho(WTP,c)=0$) in our H3 hypothesis, which captures the correlation ρ between the spatial proximity c to the afforestation project and WTP as follows:

Hypothesis H3 H_0: $\rho(WTP, c) = 0$ H_A: $\rho(WTP,c) > 0$

4. Results

We sent out 3,303 invitation emails for our survey on consumer behavior in the retail electricity market. As noted, this survey included our WTP question at the very end. A total of 359 subjects started the survey, and 160 completed it.[12] The median time participants spent answering the survey was 10.99 minutes (p10 = 4.5 minutes, p90 = 40 minutes).[13] We thus had a response rate of 5%, which is an average rate for online experiments with real people who are not members of an experimental pool.

[12] For the optimal sample size calculation, we ran a statistical power analysis. With our treatments sample size, we are able to detect a statistical power of more than 0.7. See Appendix A.5 for a detailed description of the power analysis.

[13] Due to the fixed (€20) and variable (€6–40) payment the compensation-effort ratio varies between subjects. On average participants received €27.67.

The mean participant age was 44, and 30% were female. In 2020, the average age of the German population was 44.6 years and the proportion of women was 50.7%. The *S* treatment has 73 observations, while the *CBS* treatment has 87. Balance tests on age and gender found a balanced sample. Appendix B provides a description of experimental (B.1 – B.5) and geographical (B.6 – B.8) variables. In total, the subjects donated 1,797 euros, which was used to plant 2.5[14] Caucasian walnut trees of five to six meters in height[15] in May of 2021.

4.1 Univariate Analysis of Treatment Effects

Figure 2 provides an overview of the share of participants who made a contribution, and the mean contribution amount. The share of subjects who contributed to carbon removal was larger than zero in both treatments (t-test, p=0.000). 65.0% of all subjects contributed a positive amount to the public good. In *S*, 70.0% of all subjects gave a positive amount; this share decreased to 60.9% in *CBS*. As Figure 1 shows, this decrease is not statistically significant at any conventional level (exact Fisher's test, p=0.25). We can thus reject the null hypothesis (H0: WTPS= 0) of our first hypothesis.

We continue with the subjects' implicit WTP for carbon removal. Considering only those who donated, mean WTP does not differ significantly between *S* and *CBS* (10.28 euros in *S* vs. 9.21 euros in *CBS*, t-test, p= 0.420). In relative terms, the average contributions amount to 51.2% (*S*) and 46.0% (*CBS*) of the fixed payment amount. Including all observations, the mean WTP amounts to 6.33 euros per 100 kg of annual removal. In the *S*-treatment, the mean WTP is 7.18 euros/100 kg. In the *CBS* it is 5.61 euros/100 kg. The difference in means is not significantly different (t-test, p=0.166). The regression analysis (panel B of Figure 1) confirms that highlighting local co-benefits in *CBS* has no significant effect.[16] Thus, we are unable to reject the null hypothesis ($WTP_{CBS} = WTP_S$) and we do not find support for the second hypothesis ($WTP_{CBS} > WTP_S$). These data indicate that a shift from a sole focus on carbon removal to a scenario in which local co-benefits are explicitly stressed does not lead to a higher WTP but rather – if anything – has the countervailing impact of reducing WTP.

When we compare our mean WTP to similar studies in the context of emissions avoidance, WTP for carbon removal appears to be substantially higher than the WTP for emission avoidance in Germany. Löschel et al. (2013) found a mean WTP of 1.2 euros/100kg CO_2 while Diederich and Goeschl (2014) estimated a mean WTP of 0.60 euros/100kg CO_2. These observations indicate that the

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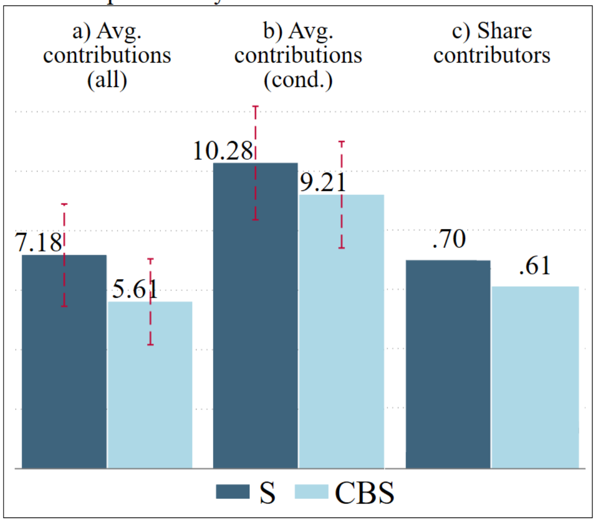
[14] The donations from this experiment were complemented with donations from another experimental study on a related topic (but with another subject pool) and jointly forwarded to the German National Garden Show such that in total four trees were planted.

[15] In contrast to other tree planting initiatives, we did not plant saplings. According to the project initiators, planting more mature trees is more efficient. Such trees are more resilient and have a higher chance of survival. The Caucasian walnut ultimately grows to a height of about 25m.

[16] Appendix Table B.9 runs the model specifications over the whole sample and finds no differences between treatments.

public valuation of forest carbon sequestration might significantly exceed that of emissions avoidance. We discuss potential reasons for this using our post-experimental survey data in Section 5.

A. Descriptive Analysis



B. Regression Analysis

	Hurdle (1)		Hurdle (2)	
	1st stage	2nd stage	1st stage	2nd stage
CBS	-0.24	-2.14	-0.23	-1.14
	(0.21)	(2.64)	(0.21)	(2.36)
Age			-0.00	0.17*
			(0.01)	(0.07)
Female			-0.19	-2.60
			(0.22)	(2.96)
Constant	0.52***	6.24*	0.63+	-0.31
	(0.15)	(2.67)	(0.33)	(4.73)
Constant	2.24*** (0.15)		2.17*** (0.14)	
Obs.	160		160	

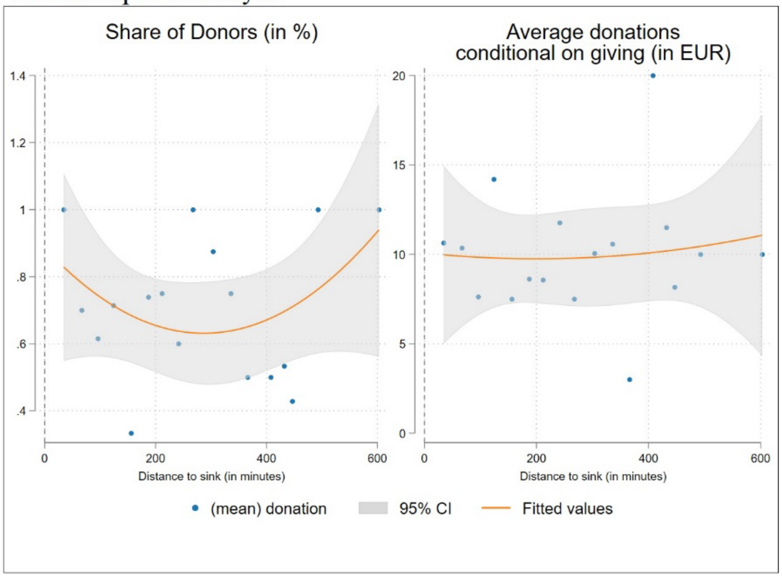
Fig 1 Extensive and intensive margin effects by treatments. Panel A shows the descriptive analysis of the contributions: (a) depicts the average amount given (in euros); (b) depicts the amount given (in euros) conditional on contributions being positive (intensive margin); (c) depicts the share of subjects that were willing to make a positive contribution (extensive margin). The dark blue bars are the results of the *S* treatment and the light blue bars of the *CBS* treatment sample. Panel B shows the corresponding regression analysis based on two (with and without further control variables) two-stage hurdle models. The first stage consists of probit regression models (where the dependent variable is equal to one for positive donations). The second stage consists of truncated linear regression models (where the continuous dependent variable is the donation amount, assuming donation is made)

4.2 Relationship between WTP and Distance

Data on participant location allows us to investigate whether the individual's distance from the forest carbon sink matters at the extensive or intensive margin. Mean subject distance from the sink was 320 km. The closest subject lived 1.7 km and the farthest 811.8 km away from the afforestation project. Looking at the distribution of subjects across Germany (see Appendix B.10), we see that participants are spread across Germany, with most subjects living rather far away (median: 302 km). For our analysis, we use a measure that is based on car travel time in minutes from the subject's location to the afforestation project. For the regression analysis, we subdivide the results of this measure into four distributional quartiles. We ultimately find a weak link between travel distance and the likelihood of contributing to the project (see Fig. 2, panel B). Due to the lower number of participants located close to the project, we cannot run a full regression analysis to identify potential correlation between our treatments and distance, as set forth in our third hypothesis. A descriptive approach (see Appendix B.11) indicates there might be some difference in propensity to donate as a function of distance.

Accordingly, we can only partially reject our third hypothesis. Averaged over both treatments, we find a correlation between donation and distance at the extensive margin, but we do not find an impact of distance on the donation amount.

A. Descriptive Analysis



B. Regression Analysis

	Hurdle	
	1st stage	2nd stage
CBS	-0.17 (0.24)	-1.12 (2.32)
Age	-0.01 (0.01)	0.17* (0.07)
Female	-0.22 (0.26)	-2.19 (2.88)
Time	-0.05 (0.04)	-0.37 (0.41)
Risk	0.04 (0.06)	0.80 (0.62)
Paternalism	-0.08 (0.05)	-0.54 (0.56)
Trust	0.06 (0.05)	0.31 (0.51)
Complexity	0.03 (0.05)	-0.19 (0.44)
Forest coverage	0.00 (0.03)	-0.23 (0.23)
Recreation space	0.04 (0.11)	-1.61 (1.02)
Agriculture space	-0.01 (0.03)	-0.34 (0.25)
Rurality	-0.02 (0.01)	-0.14 (0.14)
Wind energy	0.00 (0.00)	0.00 (0.00)
Habitat density	-0.00+ (0.00)	-0.00 (0.00)
Distance category		
2nd quartile	-1.12* (0.46)	-1.76 (4.52)
3rd quartile	-0.19 (0.42)	0.56 (4.06)
4th quartile	-0.69 (0.46)	4.19 (5.04)
Constant	3.06 (2.67)	27.81 (22.03)
Constant Hurdle	2.05*** (0.13)	
Observations	148	

Fig 2 Relationship between distance and main outcomes. Note: Panel A shows the descriptive analysis of distance on the donor share and the average conditional donations to the afforestation project measured in car travel minutes. Panel B is a regression analysis based on two-stage hurdle models. The first stage consists of probit regression models (where the dependent variable is equal to one for positive donations and zero otherwise). The second stage consists of truncated linear regression models (where the continuous dependent variable is the donation amount, assuming donation is made). The travel time quartiles are as follows: 1st quartile (0–137.2 min); 2nd quartile: 137.3–197.1 min; 3rd quartile: 197.2–329.5 min; 4th quartile: 329.6–602.6 min. Robust standard errors are in parentheses. + p < 0.10, * p < 0.05, ** p < 0.01., *** p<0.001

5. Understanding Potential Ex-Ante Priors

In contrast to expectations, our experimental results do not show increased WTP when co-benefits are emphasized. We conjecture that this stems from non-observed, ex-ante prior beliefs held by subjects. Especially in the *CBS* treatment, the individual's responsiveness to additional information may depend on his or her prior knowledge and beliefs. Accordingly, when subjects are already aware of co-benefits, highlighting them may not have the intended effect. Baranzini et al. (2018) find a similar effect: in their study, subjects already took local benefits into account, causing that study's local co-benefits treatment to be non-effective. The supposition of this causal mechanism is reasonable in our setting, as the planting of trees has become a popular and widely discussed pro-environmental measure in Germany.

Thanks to the design of our experiment, we were unable to include questions that would solicit prior knowledge and beliefs about local forest sinks. However, in order to gain some level of insight into possible priors, we conducted an additional survey of students at the University of Münster. In this survey, we assessed knowledge about and general attitudes toward donating to carbon offsetting initiatives (EU-ETS; tree planting), as well as knowledge of forest co-benefits (see Appendix C.1 for the survey). The university's Online Recruitment System for Economic Experiments was used to recruit subjects; 567 students participated. We are aware that this survey cannot perfectly substitute for the missing information in our experimental design, but we believe the results provide meaningful additional insights (see Fig 3).

First, we replicated the donation question in our experiment, but framed it hypothetically. This hypothetical framing produced almost identical values, with a mean WTP_{hyp} of 6.7 euros (vs. a $WTP_{revealed}$ of 6.3 euros) and a median WTP_{hyp} of 5 euros (vs. a $WTP_{revealed}$ of 4.6 euros). We are therefore confident that insights from this supplemental survey are informative for a better understanding of the ex-ante beliefs in our experiment.

Second, the results from our second survey coincide with our experimental finding that the public valuation of forest carbon sinks appears to be higher than that of emissions-allowance purchase and withdrawal. When asking subjects for their preferred form of donation, 48% of subjects preferred carbon removal through forests and 22% preferred emission avoidance through EU-ETS allowances. To investigate the potential reasons for such preferences, we asked subjects how much they trusted in the long-term effectiveness of carbon removal through forests and emission allowances. We find low trust in the long-term effectiveness of emission allowances (45% indicated "moderately high" to "high" trust) but high trust in carbon removal through forest (80% indicated "moderately high" to "high" trust). This is in contrast to the policy dimension of emissions avoidance being the key climate policy tool, with carbon removal only serving as a complementary tool.

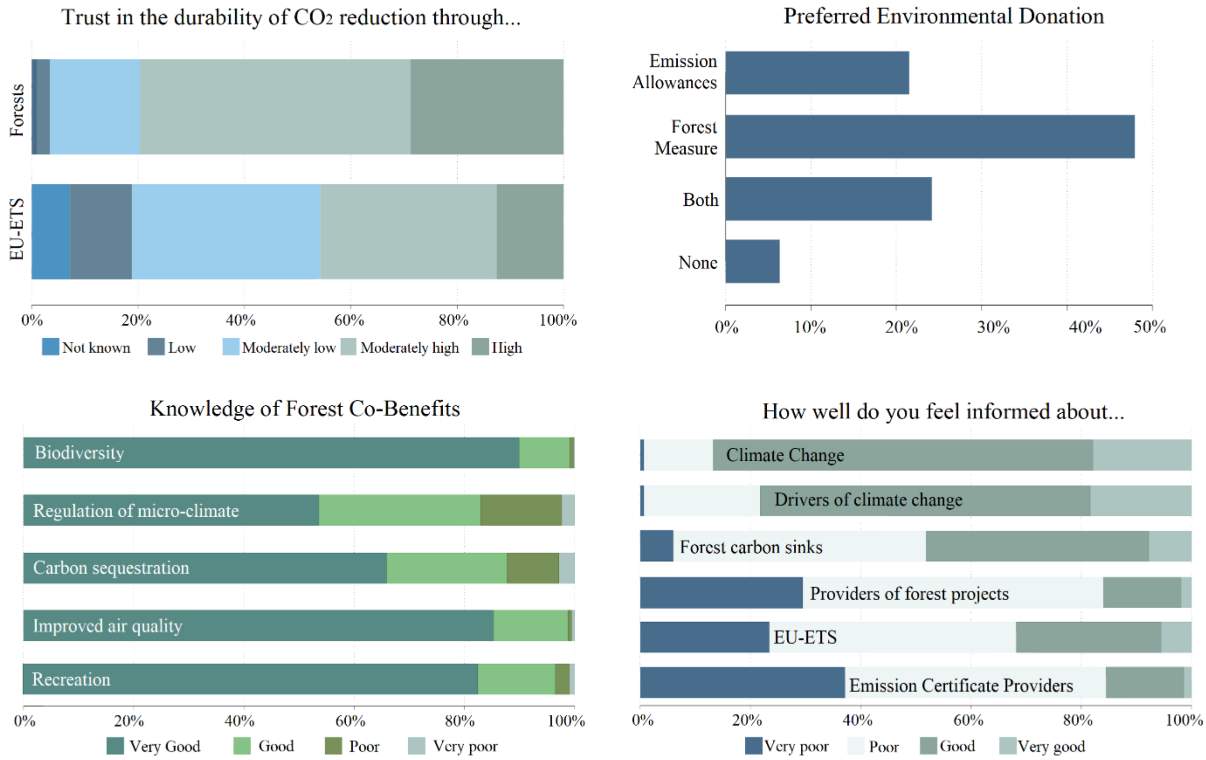


Fig 3 Survey results. Note: See Appendix C.2 and C.3 for a detailed explanation of variables.

Third, we asked subjects about their knowledge of forest co-benefits and found that subjects seemed to be well informed about all questioned co-benefits. This finding accords with our supposition that experimental subjects possess prior knowledge of co-benefits, thus causing dedicated notification of co-benefits to be non-impactful. When we investigated subject knowledge of the EU-ETS and afforestation forest measures, most subjects indicated a low level of knowledge about EU-ETS, but felt much more informed about forest measures. In Germany, numerous publicity campaigns have touted the value of tree-planting projects as a means of preventing climate change. This publicity may be the underlying reason for a higher level of knowledge about and support for forest measures compared to emission allowances. Furthermore, we conjecture that the latter may lack support due to its more abstract nature.

6. Discussion and Conclusion

While emission avoidance will necessarily remain the predominant component of the global effort to fight climate change, increased attention is being paid to CDR technologies as a means of counterbalances hard-to-abate residual emissions. In this paper, we estimated individual WTP for afforestation-based carbon removal using a revealed preferences approach. The WTP ascertained by our study diverges considerably from that of other studies on the WTP for avoidance that where – admittedly – carried out some time ago. For Germany, Löschel et al. (2013) report a mean WTP of 12 euros/tCO_2, while Diederich and Goeschl (2014) report a mean WTP of 6 euros/tCO_2. Both studies report a close to zero median WTP. Assuming linearity in marginal WTP, our results indicate a median WTP of 46 euros/tCO_2 and a mean WTP of 63.3 euros/tCO_2. Accordingly, our study finds that the population attaches higher value to forest-based carbon removal than to ETS-based emissions avoidance. Our supplementary survey of students corroborates these results. Subjects feel better informed about and have higher trust in forest measures than ETS-based avoidance. This finding accords with Gregory et al. (2016) and Wenger et al. (2021). The latter study reports that Swiss citizens are very familiar with afforestation, and that afforestation enjoys a strong reputation and strong support.

These results should be taken into consideration by policymakers as they consider future emission avoidance and removal measures. To be sure, avoidance and decarbonization must remain the primary vehicles for mitigation. It should be noted that subjects indicated a low level of knowledge and trust in EU-ETS, even though the system was established over a decade ago. Given the empirical evidence from 29 European countries on the importance of public trust for effective climate action (Carattini et al. 2015), there is clearly a need for remedial action in this area.

Our findings additionally suggest that there is a gap between public and expert assessments of options for climate action and their technical feasibility, as experts view forest carbon sinks as a supplemental (but not primary) means of addressing climate change to avoidance measures with a potential to especially decrease levels of peak warming (Matthews et al. 2022). Against this backdrop, there is a need to consider the interrelationships between avoidance and removal, including related tradeoffs. Recent results from earth system modeling suggest that CO_2 avoidance is more effective in lowering atmospheric CO_2 concentrations than an equivalent volume of CO_2 removal (Zickfeld et al. 2021). Thus, offsetting positive CO_2 emissions with carbon removal could result in different climate outcomes than an equivalent level of avoidance. Second, tree based carbon removal is considered relatively risky, as the carbon sequestration is reversible through deforestation or natural disturbances. Further uncertainties pertain to land availability and suitability as well as interactions with other ES. The inherent complexity of ecological processes and controversies surrounding development-versus-conservation conflict further exacerbate the difficulty of incorporating forest measures into official programs to mitigate climate change.

Despite these uncertainties, there seems to be a great willingness among the population to voluntarily address hard-to-reduce emissions through afforestation. We hypothesized that local co-benefits are one possible driver of this willingness and tested how highlighting such benefits impacts participant WTP. In our setting, we find no impact on revealed WTP of highlighting such benefits, compared to a setting in which co-benefits are left unmentioned. One explanation for this could be the non-observed ex-ante priors of our subjects. We were not able to control for such ex-ante priors in our experimental sample. Accordingly, we conducted an additional survey of students, which confirmed existing high knowledge of co-benefits. While the results of the student sample are not necessarily generalizable to the broader population, they provide valuable suggestive evidence and open the field for additional research. Lastly, we find weak evidence of a distance-decay effect: With increasing distance to the afforestation project, the likelihood to contribute to it decreases. This is an important insight for designing contribution appeals for such programs.

A promising path for future research would be to develop a more detailed understanding of how individual distance from an afforestation project affects donation behavior while also taking land use and availability into account. For example, the EU Regulation on Land Use, Forestry, and Agriculture obliges member states to establish natural carbon sinks equivalent to 310 million tons of CO_2 by 2030. Future research would thus be advised to consider the potential trade-offs of newly established forest carbon sinks with other ES due to potential land-use change, take into account concerns regarding permanence, additionality, leakage, and feasibility, as well as the cost of monitoring, measuring, and maintaining such sinks (Gifford 2020; Gren and Aklilu 2016; Shrestha et al. 2021; van Kooten and Johnston 2016). Such research would also benefit from interdisciplinary studies between the fields of biology, psychology, economics, and others (Fuss et al. 2020). We thus hope that our study motivates additional research on environmental donations, particularly in the context of voluntary (land based) carbon removal activities, while considering not only co-benefits, but also associated trade-offs.

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Appendix

A Background Information on the Experiment

A.1 Overview of Existing Stated and Revealed Preference Studies for Carbon Avoidance and Removal

	Stated Preference Studies	Revealed Preference Studies
TP for carbon removal	**Brey et al. (2007), Mogas et al. (2009):** CE to elicit the valuation for an afforestation program in Catalonia, Spain. Find a marginal WTP of 11.8 €. **Shrestha and Alavalapati (2004):** Report WTP estimates for moderate (high) carbon sequestration levels of silvopasture of US$ 58.1 (62.7). **Rodriguez-Entrena et al., (2012; 2014):** CE to elicit WTP for soil management program in olive groves in Andalusia, Spain. Report an aggregated annual WTP of 17.0 €/tCO_2 for carbon sequestration attribute. **Tolunay and Başsüllü (2015):** CVM approach to measure WTP for carbon sequestration service of forest in Turkey. Find average WTP per household of $23.5/year for a new forest sequestering 325,000 t/ CO_2 annually. **Torres et al. (2015):** CE to elicit the valuation and WTP for forest carbon services of afforestation project in Mexico. Participants from four different cities with mean WTPs of 5.6€, 9.2 €, 10.3€ and 11.4 € per tCO_2.	**Baranzini et al. (2018):** Investigate voluntary contributions to reforestation project to offset carbon emissions in a lab setting with a student sample. Find that participants contributed on average 6 francs of their endowment (7 francs).

WTP for carbon avoidance	**Viscusi and Zeckhauser (2006):** WTP for higher petrol taxes among Harvard graduate students. Mean WTP: \$ 0.8/ gal of petrol equaling \$ 89/tCO_2. **Brouwer et al. (2008):** Double bounded dichotomous CV design among airport visitors to elicit WTP for reducing CO_2 emissions caused by subjects' flights. Mean WTP: € 25/tCO_2. **MacKerron et al. (2009):** Dichotomous CV design to elicit WTP for hypothetical flight from New York to London. Mean WTP: £ 24/tCO_2. **Achtnicht (2012):** CE among potential German car-buyers to measure WTP for the reduction of one tCO_2. Mean WTP high (low) upper price bound: € 256.2 (89.4€) / tCO_2. **Blasch and Farsi (2012):** Reported on survey data pertaining to the mean WTP for voluntary carbon offsets. Find a mean WTP: 0.8€ - 16.0€/tCO_2 depending on emission activity. **Uehleke and Sturm (2017):** Hypothetical trade-off between a cash prize and guaranteed emissions reductions through EU-ETS. Mean WTP: € 18.8/tCO_2.	**Löschel et al. (2013):** Participants get possibility to use remuneration of € 40 to retire emissions allowances. Mean (Median) WTP: € 12 (0€) /tCO_2. **Diederich and Goeschl (2014):** Participants get trade-off between cash prize and guaranteed emissions reductions through EU-ETS. Conservative lower-bound Mean (Median) WTP: € 6 (0€) / tCO_2. **Uehleke and Sturm (2017):** Participants get trade-off between cash prize and guaranteed emissions reductions through EU-ETS. Mean WTP: € 16.2/tCO_2. **Löschel et al. (2017):** Participants get possibility to withdraw certificates from the EU-ETS using their endowment. They find a mean (median) WTP of 14.0€ (5€) /tCO_2 in their Base treatment. **Löschel et al. (2021):** Participants get possibility to use remuneration of 300 RMB (€40) to retire 1t CO_2 units from two Chinese ETS. Beijing ETS: Mean (Median) WTP = RMB 12.4 (5 RMB) / tCO_2. Shenzhen ETS: Mean (Median) WTP = RMB 3.0 (0 RMB) /tCO_2. **Feldhaus et al. (2022):** Participants get possibility to buy carbon certificates from their endowment. In the control group, the WTP is 12.8 €.

Note: We do not claim to provide a complete overview of all available studies in that domain. The table serves to illustrate the - in the opinion of the authors - most important contributions in the four categories. The only exception is the category Revealed Preferences & Afforestation.

A.2 Detailed Description of Sampling Procedure

We embedded our framed-field experiment in a study conducted jointly by the University of Münster and an online comparison platform for electricity tariffs. Participants of the experiment were invited to answer a survey. At the end of the survey we included our experimental variation. The survey was implemented with the software Qualtrics.

Participants of our experiment were registered users of that comparison platform. The online comparison platform is a tool that helps consumers to compare their current electricity tariff with other, potentially cheaper electricity tariffs. In Germany, more than 1,000 power providers exist that provide households with electricity – while they all rely on the same national energy grid, the electricity rates vary for example due to different network charges or energy mix options (renewables, coal, nuclear). For consumers it is thus often difficult to find the cheapest tariff.

To help consumers' finding the best energy tariff, there are several online comparison platform for electricity tariffs. We cannot publish the name of the comparison platform we partnered with – but they all work alike: Consumers have to enter their postal code and either how many people life in their household or their estimated electricity usage per year (measured in kilowatt-hours). In addition, there are several filtering options: contract period, green electricity, with/out price guarantee, recommendations, and others. The online comparison platform then compares all energy providers and generates a list a potential providers and the costs for the electricity contract. If consumers find a tariff that suits them, they can directly choose that tariff through the online comparison platform – the online comparison platform thus functions as intermediary between the customer and the power providers. For that, however, consumers have to enter their personal data, which are then transferred to the newly chosen power providers.

Thus, the registered users that received the personalized invitations to our experiment are consumers that in the past used and registered at the online comparison platform to find a better and cheaper power provider. These registered customers received a regular reminder from the platform to switch their electricity contract. The platform gave us a dataset with names and email addresses of the customers, which we used to send them the personalized survey invitations.

This collaboration as well as the integration of our experiment in a thematically unrelated survey, however, required some trade-offs. We were not able to stratify our selection. In addition, we only have little information on the participants' socio-economics. We are however convinced that the sample yields a good representation of the general German population. In Germany, online comparison platforms are widely used to compare energy tariffs and conclude new contract. 71\% of Germans use comparison portals (https://www.wik.org/fileadmin/Studien/2018/2017_CHECK24.pdf). Thus, the registered users of the collaborating platform should represent the German society in its heterogeneity well.

A.3 Overview of Information Provided in Treatments

	Climate protection	NETs & carbon sinks	Av. absorption of CO_2 of trees	Afforestation project	Local co-benefits
S	yes	yes	yes	yes	no
CBS	yes	yes	yes	yes	yes

A.4 Treatment Information

Note: The text is a translated version from the German original.

[**S and CBS]:** You now have the opportunity to use your remuneration to make a contribution to a climate protection project. You are completely free to decide whether and, if so, how much you wish to contribute. The following information is intended to provide you with essential background information on the selected climate protection project.

The Paris Climate Convention aims to limit global warming to 2 - preferably 1.5 - degrees Celsius above pre-industrial levels. According to the Intergovernmental Panel on Climate Change, this requires that "net emissions" of greenhouse gases such as CO_2 are rapidly reduced to zero. More precisely, zero net emissions means that the amount of greenhouse gases emitted must be at least equal to the amount of greenhouse gases removed from the atmosphere. Carbon sinks offer an opportunity to remove CO_2 from the atmosphere and thus protect the climate globally. A well-known example of a carbon sink are forests: With afforestation the carbon sequestration capacities can be enhanced. In preparation for the German Federal Horticultural Show in 2023, the City of Mannheim intends to unseal urban areas over the next few months and to then create an additional local carbon sink by planting trees of predominantly native species. According to the current state of planning, the City of Mannheim guarantees permanent maintenance by the municipal park department. You now have the opportunity to support this project of the city of Mannheim. With your contribution to the afforestation project additional trees can be planted. These trees actively remove CO_2 from the atmosphere and bind it over their lifetime. How quickly or how much CO_2 a tree binds depends on many factors, such as the tree species, its age, soil quality and water supply. For example, experts at the Forest Centre of the University of Münster calculate that a beech needs to grow for about 80 years to absorb one ton of CO_2. On average, this means a beech absorbs 100kg of CO_2 in eight years.

[**Only CBS]:** Your contribution will not only help to protect the global climate, but also creates additional habitats for animals and plants and supports local biodiversity. Besides, there are a range of other additional positive side-effects for society. Afforested areas serve as recreational and leisure areas. They improve local air quality by filtering harmful fine particles from the air, and improve the urban climate and the supply of fresh air. Especially in the summer months, afforestation can locally increase the balance of temperature and humidity extremes.

[**S and CBS]:** Please use the slider below to indicate the contribution you would like to make to the afforestation of the tree population in Mannheim.

I would like to support the removal of 100kg CO_2 from the atmosphere as part of the afforestation project with: [*Slider inserted here*]

Of course you can also decide to contribute nothing. The remaining amount of the participation fee will be sent to you in the form of a voucher as described above. After evaluating the data of all subjects, we will inform you about the results. No individual contributions will be mentioned.

A.5 Statistical Power Analysis

We base the optimal sample size calculations for our experiment on the experimental study by Löschel et al. (2021), which is closest to our design. The authors use a local sample in China and report an extensive margin effect of 31% when turning from the "local" (Beijing, 64% contribute) to the "global" setting (Shenzen, 44% contribute). To be able to detect a similar effect size, the power analysis with an underlying two-sample proportions (Pearson's χ^2 test (α=0.05, p1=0.64, p2=0.44) indicates that at least 194 experimental observations (about 97 observations per treatment) are needed to achieve a statistical power of 0.8. We were able to recruit 160 subjects for our experiment. With that, we are able to detect a statistical power of more than 0.7.

The main difference between the study by Löschel et al. (2021) and our design is that we target nationwide rather than a local sample. Moreover, we address the role of co-benefits in a treatment variation that adds further information but we do not alter the place of the donation project. So, we are "well-powered" from a purely statistical point of view for being able to detect similar treatment effects compared to those reported by Löschel et al. (2021). Differences in average treatment effects will be harder to detect in our experiment due to larger variance of responses to the intervention, e.g. the spatial distance to the local carbon sink. To cope with this, we refine our analysis by adding and controlling for distance measures and geo-data to our experimental data. In addition, given our sample size, we cannot provide a full picture of the exact functional relationship between spatial variation and the WTP. Instead, we analyze whether behavior of individuals living relatively close to the local carbon sink differs from those who are located further away.

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B: Tables and Figures

B.1 Explanation Experimental Data

Treatment	Has the value 1 when the subject is in the CBS-treatment group and 0 when s/he is in the S-treatment.
Share contributor	Has the value 1 when the subject made a contribution and 0 if s/he did not make a contribution.
Donation (cond.)	Variable indicating the amount given to the carbon sink project conditional on being a positive contributor.
Donation (all)	Variable indicating the amount given to the carbon sink project by the whole sample.
Age	Indicates the age of the subject.
Female	Has the value 1 when the subject is female and 0 otherwise.
Time	Continuous measure on a scale of 0-10, with 0 meaning "does not describe me at all" and 10 meaning "describes me perfectly". Based on the question 'I tend to put off tasks even when I know it would be better to do them right away.' The question is adapted from the Global Preference Survey (GPS) (WP13426).
Risk	Continuous measure on a scale of 0-10, with 0 meaning "does not describe me at all" and 10 meaning "describes me perfectly". Based on the question 'How willing are you to take risks?' The question is adapted from the GPS (WP13417).
Paternalism	Continuous measure on a scale of 0-10, with 0 meaning "does not describe me at all" and 10 meaning "describes me perfectly". Based on the question 'Other people often make decisions that we think are not in their best interest. How much are you willing to overrule the decisions of others to save them from what you see as bad decisions?'
Trust	Continuous measure on a scale of 0-10, with 0 meaning "does not describe me at all" and 10 meaning "describes me perfectly". Based on the question 'I suspect that people have only the best intentions.' The question is adapted from the GPS (WP13424).
Complexity	Continuous measure on a scale of 0-10, with 0 meaning "does not describe me at all" and 10 meaning "describes me perfectly". Based on the question 'I would prefer more complicated problems to simple problems'. The question is adapted from the Need For Cognition short scale.
Distance	Distance measure indicating the car travel distance in minutes between the subjects' location and the location of the carbon sink project. The variable is created in Stata with the program *osrmtime*.
Distance cat.	Categorical variable that differentiates the distance in car travel minutes to the carbon sink into four categories along the distributional quartiles [cat. 1= 1st quartile with a travel time of 0 - 137.2 minutes; cat. 2= 2nd quartile with a travel times of 137.3 - 197.1 minutes; cat. 3 = 3rd quartile with a travel times of 197.2 - 329.5 minutes; cat. 4 = 4th quartile with a travel times of 329.6 - 602.6 minutes]. For the analysis, category 1 is the base category.

B.2 Summary Statistics of Experimental Data

	N	Mean	SD	Med	Min	Max
Share contributor	160	.7	.5	1	0	1
Donation (cond.)	104	9.7	6.7	10	.9	20
Donation (all)	160	6.3	7.1	4.5	0	20
Age	160	44.1	16.8	41	18	86
Female	160	.3	.5	0	0	1
Time	159	4.4	3.1	5	0	10
Risk	159	5.4	2.3	5	0	10
Paternalism	158	6	2.4	6	0	10
Trust	159	4.6	2.6	5	0	10
Complexity	159	4.7	2.7	5	0	10
Distance	160	226.6	128.5	197.1	3	602.5

B.3 Summary Statistics of Experimental Data by Treatment

	S-Treatment (1)					
	N	Mean	SD	Med	Min	Max
Share contributor	87	0.6	0.5	1	0	1
Donation (cond.)	53	9.2	6.6	10	0.9	20
Donation (all)	87	5.6	6.8	2	0	20
Age	87	43.3	16.9	41	18	83
Female	87	0.3	0.5	0	0	1
Time	86	4.5	3.2	5	0	10
Risk	86	5.4	2.5	5.5	0	10
Paternalism	86	6.3	2.3	6.5	1	10
Trust	86	4.5	2.5	4	0	10
Complexity	86	4.4	2.9	5	0	10
Distance	87	218.6	128.5	191.5	3	602.5
	CBS-Treatment (2)					
	N	Mean	SD	Med	Min	Max
Share contributor	73	0.7	0.5	1	0	1
Donation (cond.)	51	10.3	6.9	10	1	20
Donation (all)	73	7.2	7.4	5	0	20
Age	73	45.1	16.7	42	18	86
Female	73	0.3	0.4	0	0	1
Time	73	4.2	3	4	0	10
Risk	73	5.5	2.2	5	0	10
Paternalism	72	5.6	2.5	6	0	10
Trust	73	4.8	2.7	5	0	10
Complexity	73	5	2.4	5	0	10
Distance	73	236.1	128.7	204.3	4.1	492.7

	t-test difference (1) – (2)
Share contributor	0.09
Donation (cond.)	1.07
Donation (all)	1.57
Age	1.79
Female	-0.06
Time	-0.33
Risk	0.06
Paternalism	-0.66*
Trust	0.35
Complexity	0.57
Distance	17.46

B.4 Main Outcomes in Distance Category

	Share Contributors	Donations (cond.)			Donations (all)		
		Mean	Med	N	Mean	Med	N
1st Quartile	73%	10.2	10	29	7.4	5	40
2nd Quartile	50%	8.0	6.1	22	4.4	1.7	40
3rd Quartile	45%	9.9	10	29	7.2	5	40
4th Quartile	49%	10.6	10	24	6.4	3.7	40

B.5 Main Outcomes in Distance Categories by Treatment

		Share Contributors	Donations (cond.)			Donations (all)		
			Mean	Med	N	Mean	Med	N
1st Quartile	CBS	60%	8.6	10	15	5.1	2	25
	S	90%	11.9	10	14	11.1	10	15
2nd Quartile	CBS	60%	7.6	4.5	12	4.3	2	21
	S	50%	8.6	8.6	10	4.5	1.4	19
3rd Quartile	CBS	70%	10.1	10	15	6.9	5	22
	S	80%	9.7	7.5	14	7.5	5	18
4th Quartile	CBS	60%	10.7	10	11	6.2	2	19
	S	60%	10.5	10	13	6.5	4.1	21

B.6 Explanation of Geographical Variables

Forest coverage	Indicates the area covered with forests proportional to the overall area of the administrative level 'district'. Forest areas include undeveloped land covered with trees and shrubs, but also forest patches, plant nurseries, grazing areas for big and small game.
Recreation areas	Indicates recreation area per inhabitant in m^2 in the respective 'district'. Recreational areas are undeveloped areas that are primarily used for sports, and recreation. These include green spaces as parks, allotments as well as sports fields and campsites.
Agriculture space	Indicates the area of agricultural land proportional to the overall area of the administrative level 'district'.
Urbanization level	Indicates the proportion of inhabitants in municipalities with a population density < 150 E/km^2. The indicator points to rather rural dispersed settlement structures. The variable is measured proportional to the overall area of the administrative level 'district'.
Wind energy	Indicates the installed capacity of wind energy in watts per inhabitant in the respective 'district'. The indicator provides information on the installed capacity of all wind turbines in relation to the number of inhabitants. In this sense, the municipalities are compared with regard to their efforts to contribute to the energy transition and CO_2 reduction through the generation of wind energy reduction.
Habitat density	Indicates how many inhabitants live per km^2 of settlement and traffic area in the respective 'district'.

*Note: Data are collected at the basis of NUTS-3 regions. The used administrative level is 'district', which is the smallest of German constitutionally distinct and legally independent political levels. Source: Indikatoren und Karten zur Raum- und Stadtentwicklung. INKAR. Ausgabe 2020. Hrsg.: Bundesinstitut für Bau-, Stadt- und Raumforschung (BBSR) im Bundesamt für Bauwesen und Raumordnung (BBR) - Bonn 2020. http://www.bbsr.bund.de

B.7 Summary Statistics of Geographical Variables

	N	Mean	Sd	Med	Min	Max
Forest coverage	152	23	12.5	18.5	1.7	59.5
Recreation space	152	6.1	4.7	4.7	.5	13.4
Agriculture space	152	32.8	18.2	33.5	4.1	68
Urbanization level	152	10.1	19.1	0	0	100
Wind energy	152	180.6	433	18.8	0	2849.8
Habitat density	152	3349.6	1719.9	3224.8	517.4	6287.1

B.8 Summary Statistics of Geographical Variables by Treatment

	S-Treatment (1)					
	N	Mean	SD	Med	Min	Max
Forest	69	23.9	12.1	20.1	3.8	52
Recreation	69	5.5	4.7	3.1	.5	13.4
Agriculture	69	35.3	18.4	36.3	4.1	68
Urbanization	69	14	22.5	0	0	100
Wind	69	273	577.9	26.6	0	2849.8
Habitat	69	3021.8	1637.5	3078.8	517.4	6287.1
	CBS-Treatment (2)					
	N	Mean	SD	Med	Min	Max
Forest	83	22.3	12.9	18.5	1.7	59.5
Recreation	83	6.6	4.7	6.1	.5	13.4
Agriculture	83	30.7	17.8	26.2	4.1	67.1
Urbanization	83	6.9	15.1	0	0	70.3
Wind	83	103.8	235.1	9.3	0	1655.3
Habitat	83	3622.1	1748.8	3506.5	806.9	6287.1
	t-test difference (1) – (2)					
Forest	1.6					
Recreation	-1.1					
Agriculture	4.6					
Urbanization	7.1**					
Wind	169.2**					
Habitat	-600.3**					

B.9 Regression Analysis

	OLS (1)	OLS (2)	OLS (3)	OLS (4)	OLS (5)
CBS	-1.57 (1.13)	-1.35 (1.12)	-0.67 (1.13)	-1.08 (1.20)	-1.05 (1.20)
Age		0.06^{+} (0.03)	0.06^{+} (0.03)	0.06^{+} (0.04)	0.05 (0.04)
Female		-1.74 (1.23)	-1.70 (1.24)	-1.78 (1.27)	-1.85 (1.27)
Time			-0.25 (0.18)	-0.10 (0.19)	-0.18 (0.19)
Risk			0.57^{*} (0.27)	0.22 (0.28)	0.38 (0.30)
Paternalism			-0.55^{*} (0.25)	-0.34 (0.26)	-0.42 (0.27)
Trust			0.33 (0.23)	0.24 (0.24)	0.29 (0.24)
Complexity			-0.10 (0.22)	0.02 (0.23)	-0.02 (0.23)
Forest coverage				-0.05 (0.13)	-0.10 (0.13)
Recreation space				-0.52 (0.50)	-0.48 (0.52)
Agriculture space				-0.10 (0.14)	-0.17 (0.14)
Urbanization density				-0.10^{+} (0.05)	-0.08 (0.06)
Wind energy				0.00 (0.00)	0.00 (0.00)
Habitat density				-0.00 (0.00)	-0.00 (0.00)
Distance cat. 2nd quartile					-3.61 (2.23)
Distance cat. 3rd quartile					-0.42 (2.04)
Distance cat. 4th quartile					-1.08 (2.30)
Constant	7.18^{***} (0.83)	4.73^{**} (1.79)	4.52 (2.93)	13.48 (12.02)	21.89^{+} (12.79)
Observations	160	160	156	148	148
Adjusted R^2	0.006	0.033	0.068	0.032	0.040

Note: Models 1-5 are linear regression models. The continuous dependent variable is the amount given to the afforestation project considering the whole sample. Distance is a categorical variable indicating the travel time between the subjects' location and the afforestation project. The base value is the 1st quartile includes travel times of 0 - 137.2 minutes, the 2nd quartile includes 137.3 - 197.1 minutes, the 3rd quartile includes 197.2 - 329.5 minutes, and the 4th quartile includes 329.6 - 602.6 minutes. Robust standard errors are in parentheses. +(*, **, ***) means 10% (5%, 1%, 0,1%) significance level.

B.10 Spatial Distribution of Participants

B.11 Distribution of the share of donors and the donations along the spatial dimension

C Background Information on Additional Student Survey

C.1 Survey Questionnaire

Note: The text is a translated version of the German original.

Page 1

In the past, subjects of our studies have repeatedly asked us for the opportunity to donate part of their remuneration to projects protecting the climate and the environment. Please imagine you are a participating in such an incentivized study and answer the following questions against this background.

As you may know, there are different ways to make a contribution for the environment and climate protection. Consider the following two donation options:

- Retirement of CO_2 allowances under the European Emissions Trading Scheme. Once a CO_2 allowance is purchased it can no longer be used for entitlement to emit CO_2 on the market
- An afforestation project in Germany

In the context of such an environmental donation, would you generally prefer to have the opportunity to set aside CO_2 certificates as part of the European Emissions Trading Scheme, or would you prefer to support an afforestation project in Germany?

☐ Rather purchase CO_2 certificates
☐ Rather support afforestation project
☐ I would equally endorse both projects as a donation option
☐ I would not support either project as a donation option

Page 2

Please think again about the afforestation project. How good is your knowledge of the following functions of a forest?

	Very good	Good	Poor	Very poor	No Answer
Biodiversity / Habitat for plants and animals					
Raw material supplier					
Regulation of the microclimate					
Carbon sequestration					
Water reservoir for flood protection					
Water filter for clean groundwater					
Protection against erosion					
Improvement of local air quality					
Noise protection					
Recreation					
Sports					

Page 3

Trees can absorb and bind CO_2 over the course of their lives as they grow. Please imagine again that have the opportunity to support an afforestation project.

- How many tons of CO_2 do you think an 80-year-old beech tree can sequester? [Slider]
- What is the corresponding emission value of a distance traveled by a car (in km) of this value? [Slider]
- Assume that participation in the study would be remunerated with 20 EUR, for which you would have to answer a questionnaire. Answering the questionnaire takes about 20 minutes. After answering the questionnaire, you have the opportunity to donate your remuneration in parts or fully. How much would you be willing to donate for the sequestration of 100kg of CO_2 within the afforestation project?

Page 4

How quickly or how much CO_2 a tree can sequester depends on numerous factors, such as the type and age of the tree, the soil quality and its water supply. Accordingly, data on the CO_2 sequestration potential of forests varies depending on the calculation base. Experts at the Forest Center of the University of Münster estimated that a beech must grow for about 80 years to absorb one ton of CO_2. On average, this means a beech can absorb 100kg of CO_2 in eight years. This corresponds roughly to the emission value of a distance traveled by a car of about 550 km.

After having received this information, would you want to adjust your donation from the previous page?

☐ Yes, I would like to increase the donation amount (to_____€)
☐ Yes, I would like to decrease the donation amount (to____€)
☐ No, I would not change the donation amount

Page 5

	Low	Moderately low	High	Moderately high	Never heard of this	No Answer
How high is your trust in the durability of CO_2 reduction through forests?						
How high is your trust in the durability of CO_2 reduction through the purchase of emission allowances?						

Page 6

In the following, we are in your basic assessment regarding various climate protection measures. How much do you agree with the following statements?

	Strongly agree	Agree	Disagree	Strongly disagree	No answer
Afforestation is a useful and sustainable climate protection measure					

Emissions trading can make a decisive contribution to climate protection					
Emissions trading alone is not enough to achieve emissions targets					
Especially natural approaches such as afforestation projects should be additionally used to reduce CO_2					

Page 7

Finally, we would now like to know how good you feel informed about...

	Very good	Good	Poor	Very Poor	No answer
…climate change in general					
…the drivers of climate change					
…climate regulation and carbon sequestration by forests					
…providers of compensation services from forest projects					
…the European emissions trading system					
…providers of emission allowance set-asides or voluntary CO_2 offsets					

C.2 Explanation of Survey Variables

Trust in durability of CO_2 removal… Scale: 1 = not known, 2 = low, 3 = moderately low, 4 = moderately high, 5 = high	
... by forests	Indicates how much subject trusts that forests permanently remove CO_2 from the atmosphere
…through emission allowances	Indicates how much subject trusts that CO_2 allowances permanently remove CO_2 from the atmosphere
Informed on… Scale: 1 = very poor, 2 = poor, 3 = good, 4 = very good	
… climate change	Indicates how well subject feels informed about climate change in general
… climate change drivers	Indicates how well subject feels informed about the drivers of climate change
… forests as carbon sink	Indicates how well subject feels informed about climate regulation and carbon sequestration by forests
… forest project providers	Indicates how well subject feels informed about providers of compensation services from forest projects
… EU ETS	Indicates how well subject feels informed about the European emissions trading
… certificate providers	Indicates how well subject feels informed about providers of emission allowances or voluntary CO_2 offsets
Knowledge of forest co-benefit … Scale: 1 = very good, 2 = good, 3 = poor, 4 = very poor	
… biodiversity	Indicates whether biodiversity is a forest function known to the subject
… regulation of micro-climate	Indicates whether the regulation of the microclimate is a forest function known to the subject
… carbon sequestration	Indicates whether sequestration of carbon is a forest function known to the subject
… air quality improvement	Indicates whether the improvement of air quality is a forest function known to the subject
… recreational value	Indicates whether the recreational value of a forest is known to the subject
Hypothetical environmental donation	The subject should for the question imagine that s/he gets 20 EUR for answering a questionnaire, which takes about 20 minutes. After answering the questionnaire, you s/he has the opportunity to donate the remuneration. The variable indicates how much the subject would hypothetically donate for the sequestration of 100kg of CO_2 within an afforestation project.
Preferred environmental donation	Indicates whether the subject would prefer an environmental donation to set aside CO_2 certificates (EU ETS), or to support an afforestation project in Germany, or none.

C.3 Summary Statistics of Survey Variables

	N	Mean	SD	Min	Max
Durability forests	556	4	.8	1	5
Durability emission allowances	540	3.3	1.1	1	5
Info on climate change	566	3	.6	1	4
Info on climate change drivers	565	3	.6	1	4
Info on forests as carbon sink	565	2.5	.7	1	4
Info on forest project providers	563	1.9	.7	1	4
Info on EU ETS	564	2.1	.8	1	4
Info on certificate providers	559	1.8	.7	1	4
Know co-benefit: biodiversity	567	1.1	.4	1	4
Know co-benefit: regulation microclimate	563	1.7	.8	1	4
Know co-benefit: carbon sequestration	563	1.5	.8	1	4
Know co-benefit: air quality improvement	567	1.2	.4	1	4
Know co-benefit: recreational value	563	1.2	.5	1	4
Preferred environmental donation					
Emission allowances	567	.2	.4	0	1
Forest project	567	.5	.5	0	1
Both	567	.2	.4	0	1
None	567	.1	.2	0	1
Hypothetical environmental donation	567	6.8	5.8	0	20

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