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September 2014

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Abstract

This paper provides theoretical and empirical insights on the extent to which the availability of carbon offsetting may substitute the individual use of other carbon-reducing measures. Theoretically, we demonstrate an ambiguous impact of offsetting on the use of other measures and derive conditions under which both are substitutes or complements. We then empirically test our predictions using data from representative surveys among more than 2000 citizens in Germany and the U.S. Considering seven measures that can be taken by individuals to directly reduce greenhouse gas emissions, our empirical evidence is consistent with the theoretical predictions that substitution occurs particularly if individuals lay a sufficiently large weight on environmental preference or if offsetting is perceived to be relatively effective in providing the public good climate protection. Complementary effects are shown to exist for a perceived intermediate effectiveness of offsetting activities.

Keywords: climate change; climate protection; green consumption; carbon offsetting; complement; substitute; impure public goods

JEL: C25, Q54, Q58

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1. Introduction

Voluntary carbon offsetting is being promoted to individuals, firms, and organizations as a promising way to reduce their carbon footprint and to help mitigating climate change. By investing in climate protection projects, they can compensate their carbon emissions originating from consumption activities, such as driving, flying, heating buildings, or electricity use. Instead of directly avoiding such emissions, which may be impossible or relatively costly and time-consuming, investments in voluntary offsets may save costs and at the same time may enhance reputation or emotional well-being (e.g., Kollmuss et al., 2008; Kotchen, 2009a; MacKerron et al., 2009).

Such offsetting activities do, however, also face substantial criticism: first, paying others to compensate for own environmental "sins" may have a negative connotation (e.g., Kotchen, 2009a).[1] Second, the procedure may encourage a larger consumption of polluting goods and activities and thereby lead to even higher greenhouse gas emission levels rather than reducing them.[2] That is, the environmental impact of the purchase of voluntary offsets may be ambiguous if offsetting substitutes other climate protection activities. In this paper, we theoretically and empirically investigate the existence of such substitution effects.

So far, only a small body of literature is concerned with the relationship between offsetting options and other climate protection activities. In his general model of pro-environmental consumption, Kotchen (2005) is the first to account for the availability of substitutes for green products and the impact of consumer preferences for the private and the public characteristic. He also analyzes the effects of the possibility of purchasing offsets and shows that free-riding in large economies is reduced due to their presence (Kotchen, 2009b). In the context of green electricity consumption[3], Kotchen and Moore (2008) find a complementary relationship between participation in green-electricity programs and energy saving efforts for non-conservationists, while conservationists do not change their energy consumption after participating in green-energy programs. But households purchasing a minimum amount of green electricity increase their electricity consumption indicating a substitution effect which does not occur for households purchasing higher amounts of green electricity (Jacobsen et al., 2012).

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[1] Some critics even compare the concept of voluntary offsetting to the old practice of buying indulgences from the Catholic Church (e.g., Kotchen, 2009b; Lange and Ziegler, 2012).

[2] The potential of adverse environmental effects from offsetting is comparable to a rebound effect which may, for example, result from energy-efficiency improvements and lead to behavioral responses (e.g., Frondel, 2004). Such side effects have the potential to decrease or even reverse the intended impact of environmental policies and have to be taken into account by policy makers and regulators (e.g., Gans and Groves, 2012).

[3] Participation in green-electricity programs is comparable to donations for climate protection if consumers pay a price premium for using the cleaner alternative.

Lange and Ziegler (2012) show theoretically that offsets can be expected to reduce emission levels while not necessarily increasing the consumption of a polluting good in the context of vehicle purchases. Their empirical findings indicate that the purchase of offsets and voluntary mitigation activities by driving license owners in Germany and the U.S. are mainly driven by environmental preferences as well as a high awareness of the negative impacts of climate change and the perception of road traffic as being responsible for carbon emissions. Gans and Groves (2012) apply offsetting to a model of the electricity market and find that voluntary purchases of offsets are most likely to reduce emission levels. Chan and Kotchen (2014) enrich this discussion by generalizing the impure public good model. The authors argue that an increased contribution of a green good to environmental quality may increase its consumption and decrease direct donations if private and environmental characteristics enter individual utility as substitutes. The reverse result may hold if private and public characteristics are complements in generating individual utility. In this context, Blasch and Farsi (2014) empirically show that individuals with a low carbon footprint are more likely to offset their remaining carbon emissions, thereby indicating a complementary relationship between offsetting and other climate protection activities.

Offsetting and other climate protection activities form different channels through which an individual may voluntarily contribute to climate protection. They differ in their monetary costs, but also along other dimensions, e.g. time. The literature on charitably giving which investigates giving along different dimensions, e.g. money vs. time donations, can therefore provide relevant insights:[4] donations of time and money were theoretically predicted to be perfect substitutes (e.g., Duncan, 1999), while empirical studies reveal complementary interdependences between cash donations and volunteer labor (e.g., Brown and Lankford, 1992; Mellström and Johannesson, 2008). Furthermore, offsetting puts a price tag on voluntary carbon reductions. Introducing prices for otherwise "voluntary" prosocial activities, i.e. extrinsic motivation, has been found to potentially crowd out intrinsic motivation (e.g., Gneezy and Rustichini, 2000; Brekke et al., 2003; Bénabou and Tirole, 2006; Falk and Kosfeld, 2006). A related literature on moral-licensing and self-balancing also predicts that pro-environmental activities give individuals a license to choose polluting consumption alternatives in the future and that previous dirty consumption may lead to compensatory measures in order to improve self-image and regain a balanced moral account (e.g., Clot et al., 2014; Croson and Treich,

[4] While offsetting may be associated with money donations, choosing other (costly) climate protection activities may change the perceived quality of a private consumption good or may be more time consuming (e.g., car travel vs. public transport). Individuals also need time for changing habits in order to save energy at home or for finding adequate alternatives in order to reduce the consumption of meat or dairy products.

2014). Recent theoretical, empirical and experimental work shows that self-image and moral balance are important factors explaining individual decision making (e.g., Stringham, 2011; Ploner and Regner, 2013; Tiefenbeck et al., 2013). Greenberg (2014) discusses prosocial behaviors in light of complementary or substitutionary relations between underlying social norms.

In this paper, we investigate under which conditions offsetting options and other climate protection activities may be substitutes or complements. We both contribute to the theoretical literature on private provisions of public goods and provide empirical evidence by conducting a cross-country analysis. In Section 2, we explicitly model the consumption patterns of clean vs. dirty products in the presence of offsets. We show that complementarities between offsetting options and using cleaner options to satisfy private consumption needs can only be expected for intermediate effectiveness of offsets in generating the public good (or feelings of warm glow from environmentally friendly behavior). As long as the cleaner option is more expensive than the dirty alternative, full substitution of the cleaner option is predicted when offsets become highly effective. That is, individuals revert to using more dirty instead of cleaner consumption options due to the availability of effective offsetting. As such, the impact of offsetting on the consumption patterns is potentially ambiguous.

Based on this theoretical modeling, in Sections 3 and 4 we examine the impact of individual purchases of carbon offsets on the stated willingness to choose cleaner consumption alternatives.[5] While prior research has focused on green electricity (e.g., Kotchen and Moore, 2008; Jacobsen et al., 2012), we consider a wide range of seven climate protection activities which can be taken by individuals in order to reduce greenhouse gas emissions. We analyze the effect of offsetting purchases on the stated willingness to use cleaner consumption alternatives and include several interactions with financial advantages associated with the climate protection activity, the perceived effectiveness of offsetting and the climate protection activity in providing climate protection as well as with environmental preferences and warm glow motives. Using data from unique representative surveys among overall more than 2000 citizens in Germany and the U.S., we demonstrate that without considering these interactions, offsetting seems to be rather complementary to other climate protection activities in both countries, although individuals substitute certain clean consumption alternatives by offsetting if they lay a sufficiently large weight on environmental preference or if offsetting is perceived to be relatively effective in providing the public good climate protection.

[5] This approach differs from the one pursued in the aforementioned study of Blasch and Farsi (2014) who use environmentally conscious behavior as a determinant for the demand of carbon offsets.

The final Section 5 summarizes our theoretical and empirical findings and draws some important conclusions.

2. Theoretical Predictions

We formulate a model in the tradition of Kotchen (2005, 2009b) to capture an individual's demand for private consumption and a public good. The utility function of individual i is given by

$$u_i(c_i, x_i, y_i)$$

where c_i denotes the consumption of a numeraire (money), x_i is the consumption of a private characteristic (e.g., the private consumption of driving a car) and y_i denotes the individual's contribution to a public good.[6] Here, $u_i(c_i, x_i, y_i)$ is an increasing and quasi-concave utility function.

Individuals can spent income w_i on the numeraire c_i, a private good g_i^d, interpreted as a dirty good "*d*", and an impure public good g_i^c, the clean(er) alternative "*c*", whose consumption contributes to the public good at rate β_i^c and to the private characteristic at rate α_i^c, respectively.[7] Each dollar spent on offsets g_i^ocontributes to the public good at rate β_i^o.Therefore:

$$x_i = \alpha_i^c g_i^c + g_i^d \qquad\qquad y_i = \beta_i^o g_i^o + \beta_i^c g_i^c$$

Prices for all goods are normalized to one such that the budget constraint is given by

$$c_i + g_i^o + g_i^c + g_i^d \leq w_i.$$

While Kotchen (2005, 2009b) is concerned with the impact of introducing an impure public good on the level of the environment, we study how the option of offsetting (direct donations) affects the consumption of impure public goods. This is captured by varying the effectiveness parameter β_i^o, i.e. no offsetting possibilities correspond to $\beta_i^o = 0$, while offsetting could only be a reasonable option if $\beta_i^o > \beta_i^c$ since buying only impure public goods would otherwise dominate.

Modelling three consumption options, a private good, an impure public good, and offsets, allows us to investigate the determinants of consumption patterns along two dimensions: (i)

[6] In Kotchen (2009b), this is defined as a public good to which other individuals can also contribute, i.e. $Y = y_i + Y_{-i}$. Here, we concentrate on individual decision only, taking as given the behavior of other players. Our modeling approach therefore corresponds to a warm glow approach by Andreoni (1993).
[7] Alternatively, one could allow for a negative contribution from the dirty good and a less negative or positive contribution rate from the clean(er) alternative. This would not qualitatively change our results.

individuals may substitute some dirty consumption for cleaner alternatives. (ii) they may purchase offsets in order to directly contribute to the public good. We explore how the availability of offsets and an increased effectiveness β_i^o of their use[8] change the consumption patterns for the clean and dirty alternatives.

In order to derive optimal demand, it is helpful to first solve the following cost minimization problem

$$\min g_i^o + g_i^c + g_i^d \text{ such that } x_i \le \alpha_i^c g_i^c + g_i^d \text{ and } y_i \le \beta_i^o g_i^o + \beta_i^c g_i^c$$

We immediately obtain the following cases:

(A.1) $\alpha_i^c \ge 1, 1 - \frac{\beta_i^c}{\beta_i^o} < 0$: $g_i^c = \max\left\{\frac{x_i}{\alpha_i^c}, \frac{y_i}{\beta_i^c}\right\}$, $g_i^d = 0$, $g_i^o = 0$.

(A.2) $\alpha_i^c \ge 1, 1 - \frac{\beta_i^c}{\beta_i^o} > 0$: $g_i^c = \frac{x_i}{\alpha_i^c}$, $g_i^d = 0$,

$g_i^o = \max\left\{0, \frac{\alpha_i^c y_i - \beta_i^c x_i}{\beta_i^o \alpha_i^c}\right\}$.

(B.1) $\alpha_i^c < 1, 1 - \frac{\beta_i^c}{\beta_i^o} < 0$: $g_i^c = \frac{y_i}{\beta_i^c}$, $g_i^d = \max\left\{0, \frac{\beta_i^c x_i - \alpha_i^c y_i}{\beta_i^c}\right\}$,

$g_i^o = 0$

(B.2) $\alpha_i^c < 1, 1 - \alpha_i^c - \frac{\beta_i^c}{\beta_i^o} < 0 < 1 - \frac{\beta_i^c}{\beta_i^o}$: $g_i^c = \min\left\{\frac{x_i}{\alpha_i^c}, \frac{y_i}{\beta_i^c}\right\}$,

$g_i^d = \max\left\{0, \frac{\beta_i^c x_i - \alpha_i^c y_i}{\beta_i^c}\right\}$, $g_i^o = \max\left\{0, \frac{\alpha_i^c y_i - \beta_i^c x_i}{\beta_i^o \alpha_i^c}\right\}$

(B.3) $1 - \alpha_i^c - \frac{\beta_i^c}{\beta_i^o} > 0$: $g_i^c = 0$, $g_i^d = x_i$, $g_i^o = \frac{y_i}{\beta_i^o}$

Note that cases (A.1) and (A.2) comprise a situation where $\alpha_i^c \ge 1$, i.e. where the clean consumption good is superior to the dirty one even in generating the private characteristic. Here, the dirty good will never be consumed. In (A.1), the individual consumes only the clean good as this dominates offsets in the production of the public characteristic ($\beta_i^c > \beta_i^o$). In (A.2), offsetting may additionally be used. When $\alpha_i^c < 1$ and a low effectiveness of offsets, case (B.1), the clean good dominates offsetting in the production of the public characteristic such that the clean and possibly the dirty alternative are used. In (B.2), the clean alternative and either the dirty alternative or offsetting are consumed, depending on the demand for y_i vs. x_i.

[8] An increase in the effectiveness of offsets could equivalently be modeled as a reduction in their price.

Finally, in case (B.3) of highly effective offsetting, the clean alternative is not used as it is dominated by a combination of the dirty alternative and offsets.[9]

These considerations already show that an individual who uses a clean good when no offsetting options are available ($\beta_i^o = 0$) may fully substitute its use ((B.1) to (B.3)) when offsetting becomes highly effective. This would not occur, however, if the clean alternative already dominates the dirty one in terms of providing the private characteristics, i.e. saves costs relative to using the dirty alternative ((A.1) to (A.2)).

It is instructive to illustrate these cases in terms of the budget sets for consuming the characteristics (c_i, x_i, y_i). The budget sets for the cases (A.2), (B.2) and (B.3) are illustrated in Figure 1. The budget frontiers consist of either two (in case (B.2)) or one (in case (A.1) and (B.3)) facets. This geometric representation already lends insights into the impact of offsetting options on possible consumption choices. If $\alpha_i^c \geq 1$ and without effective offsetting ($\beta_i^o \leq \beta_i^c$), offsetting will not take place (the budget set collapses to the bold line in (A.2), while the optimal consumption may move into the interior of the facet for $\beta_i^o > \beta_i^c$).

For $\alpha_i^c \geq 1$ and $\beta_i^o \leq \beta_i^c$, the upper left facet in (B.2) would be dominated by the right lower facet. We denote the optimal consumption levels without offsetting options by (c_i^0, x_i^0, y_i^0). For intermediate cases ($\beta_i^c \leq \beta_i^o \leq \frac{\beta_i^c}{1-\alpha_i^c}$), both facets of the budget set frontier in case (B.2) exist. It is, however, obvious that – for convex preferences – the consumption choice will not change if consumption without offsetting options (c_i^0, x_i^0, y_i^0) was in the interior of the lower right facet. That is, offsetting will continue *not* to be used. Only if (c_i^0, x_i^0, y_i^0) was chosen along the bold line which separates the two facets in (B.2), i.e. did not involve any consumption of the dirty good, consumption may move into the interior of the upper right part of the budget frontier. In this range, the consumption patterns thus are similar to (A.2) as no dirty good is used. We will consider the impact of an increased offsetting effectiveness β_i^o on the consumption of the clean(er) good in this case below. Finally, in case (B.2) where the effectiveness of offsets is large ($\beta_i^o > \frac{\beta_i^c}{1-\alpha_i^c}$), the clean good would be dominated by combinations of the dirty good and offsetting.

[9] To mimic the private and public characteristics produced by one unit of the cleaner good (α_i^c, β_i^c), a combination of α_i^c units of the dirty good and β_i^c/β_i^o units of offsets could be used and would be less costly.

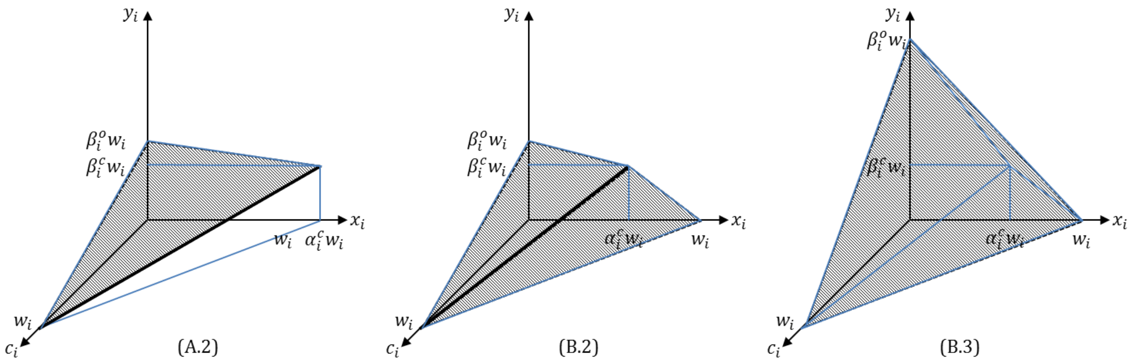

Figure 1: *Illustration of budget sets. Case* (A.2)*: clean consumption and offsetting (in the interior of the facet, only clean consumption along the bold line). Case* (B.2)*: consumption involves no offsetting (lower right facet of the budget frontier) or no consumption of the dirty good (upper left facet of budget frontier). Case* (B.3)*: Consumption of clean good is dominated by combinations of dirty good and offsetting.*

If consumption in case ($\beta_i^c \leq \beta_i^o \leq \frac{\beta_i^c}{1-\alpha_i^c}$) is in the interior of the upper left triangular facet of the budget frontier (in (B.2) or in the interior of the budget set in (A.2)), we have $g_i^d = 0$, $g_i^c = \frac{x_i}{\alpha_i^c}$ and $g_i^o = \frac{\alpha_i^c y_i - \beta_i^c x_i}{\beta_i^o \alpha_i^c}$. As such, we can rewrite the (relevant) budget constraint as:

$$c_i + x_i \frac{1}{\alpha_i^c}(1 - \frac{\beta_i^c}{\beta_i^o}) + \frac{1}{\beta_i^o} y_i \leq w_i$$

and define the implicit prices for private and public characteristics as $p_x = \frac{1}{\alpha_i^c}(1 - \frac{\beta_i^c}{\beta_i^o})$ and $p_y = \frac{1}{\beta_i^o}$. In order to derive how increases in the effectiveness of offsetting β_i^o may impact individual consumption choices of the impure public good in this range, we follow the technique by Chan and Kotchen (2014) to obtain:

$$\frac{dx_i}{d\beta_i^o} = \frac{\partial x_i}{\partial p_x}\frac{dp_x}{d\beta_i^o} + \frac{\partial x_i}{\partial p_y}\frac{dp_y}{d\beta_i^o} = \frac{\partial x_i}{\partial p_x}\frac{1}{\alpha_i^c}\frac{\beta_i^c}{(\beta_i^o)^2} - \frac{\partial x_i}{\partial p_y}\frac{1}{(\beta_i^o)^2}.$$

Using the typical Slutsky decomposition into compensated price responses and income effects, we obtain

$$\frac{dx_i}{d\beta_i^o} = \left(\frac{\partial \bar{x}_i}{\partial p_x} - x_i^* \frac{\partial x_i}{\partial w_i}\right)\frac{1}{\alpha_i^c}\frac{\beta_i^c}{(\beta_i^o)^2} - \left(\frac{\partial \bar{x}_i}{\partial p_y} - y_i^* \frac{\partial x_i}{\partial w_i}\right)\frac{1}{(\beta_i^o)^2}.$$

where $\frac{\partial \bar{x}_i}{\partial p_x}$ and $\frac{\partial \bar{x}_i}{\partial p_y}$ are the compensated price responses and x_i^* and y_i^* denote the optimal choices. Using $g_i^o = \frac{\alpha_i^c y_i - \beta_i^c x_i}{\beta_i^o \alpha_i^c}$, we can rewrite this expression to obtain:

$$\frac{dx_i}{d\beta_i^o} = \frac{\partial \bar{x}_i}{\partial p_x}\frac{1}{\alpha_i^c}\frac{\beta_i^c}{(\beta_i^o)^2} - \frac{\partial \bar{x}_i}{\partial p_y}\frac{1}{(\beta_i^o)^2} + g_i^{o,*}\frac{\partial x_i}{\partial w_i}\frac{1}{\beta_i^o}.$$

Here, the first expression is negative and relates to a direct substitution effect. The third is positive as long as x_i is normal with respect to income which we assume. The sign of the second term depends on whether private and public characteristics enter the utility as net substitutes ($\frac{\partial \bar{x}_i}{\partial p_y}$ positive) or net complements ($\frac{\partial \bar{x}_i}{\partial p_y}$ negative). It thus becomes obvious that the positive income effect combined with complementarities between private and public characteristics may trigger the consumption of the clean good to increase in response to more effective offsetting options.

The potentially ambiguous impact of offsetting options on the consumption of the impure public good demonstrates that the availability of offsetting does not necessarily crowd out other clean goods. Instead, both may be complementary. However, we want to highlight again that such a (local) complementarity may only occur if the clean good already dominates the dirty good in generating the private characteristic (i.e. is less costly, $\alpha_i^c > 1$) as in case (A.2), or for intermediate ranges of the offsetting effectiveness ($\beta_i^c \leq \beta_i^o \leq \frac{\beta_i^c}{1-\alpha_i^c}$) and if individuals have a strong enough preference for the public characteristic such that they would not consume the dirty good when offsets are not available. Individuals will stop consuming the clean technology if $\beta_i^o > \frac{\beta_i^c}{1-\alpha_i^c}$ (and $\alpha_i^c \leq 1$). This extreme prediction clearly only results if clean and dirty consumption alternatives are perfect substitutes in generating the private good as assumed in our model. For less perfect substitutability, both alternatives may continue to be used.

A positive correlation between the usage of offsetting and consumption of impure public goods may also result when comparing choices across individuals as those may differ in income and/or their preferences. As a consequence, we carry out an empirical analysis to investigate the interrelation between voluntary climate protection activities and carbon offsetting.

3. Data and variables

The empirical analysis is based on representative data from self-administered online surveys among a total of 1005 citizens in Germany and 1010 citizens in the U.S. aged 18 and older. The surveys were carried out simultaneously in May and June 2013 by the market research company GfK SE (Gesellschaft für Konsumforschung) drawing the sample from the GfK Online Panel based on the official population statistics of the two countries. The completion of the survey required about 30 minutes on average in both countries. Survey questions were carefully pretested and encompassed general personal assessments of climate change, specific attitudes towards international climate policy and negotiations, fundamental values as well as individual engagement in climate protection activities and carbon offsetting.

Specifically, the respondents were asked which of the following clean consumption alternatives they are planning to take in the future: buying energy-efficient appliances, actions to save energy at home, reducing the consumption of meat or dairy products, using or purchasing energy from renewable sources, buying a car with lower fuel consumption, reducing car use, and reducing the number of flights.[10] Based on the binary structure of the response options, we construct seven dummy variables that serve as dependent variables in our analyses.[11] Our main explanatory binary variable *offsetting* indicates that the respondent already engaged in offsetting in the past to compensate the carbon emissions caused by her.

In addition to these variables which capture individual consumption patterns of the clean consumption alternative and offsets, we also include explanatory variables reflecting individual tastes and preferences which may influence these consumption patterns. The dummy variables *high contribution of clean good* and *financial advantages of clean good* reflect respondents' beliefs that the seven clean consumption alternatives contribute rather a lot or a lot to climate protection (capturing β_i^c in the model) and provides rather financial advantages for her personally (corresponding to $\alpha_i^c > 1$ in which case the climate protection activity dominates the dirty alternative), respectively. Similarly, *high contribution of offsetting* captures the perceived effectiveness of offsetting options (capturing β_i^o in the model). For measuring environmental preferences, we use six items from the New Environmental Paradigm (*NEP scale*) (Dunlap et al., 2000)[12] and additionally include an indicator for *warm glow* motives. Table 2 in the Appendix provides a full list of explanatory variables (including several socio-economic control variables) and their definitions.

Table 3 reports the descriptive statistics on the dependent and explanatory variables for our samples of 1005 German and 1010 U.S. respondents. Although about one half of the respondents in both countries believe that offsetting contributes (rather) a lot to climate protection, only eleven percent in Germany and 14 percent in the U.S. already engaged in carbon offset-

[10] We use the stated willingness to take one of the clean consumption alternatives in the future, although we also collected the information whether respondents engaged in climate protection activities in the past. But since we have no time reference on the purchase of offsetting and the use of the clean consumption alternative, it does not seem to be reasonable to compare past offsetting with clean consumption in the past.
[11] Table 1 in the Appendix provides a full list of dependent variables and their definitions.
[12] The NEP scale is a standard instrument in the social and behavioral sciences and is also increasingly common in the economic literature (e.g., Kotchen and Moore, 2007).

ting in the past, respectively. On average, contributions to climate protection of the clean consumption alternatives are rated slightly higher compared to offsetting with one exception: only 35 percent of the respondents in Germany and 25 percent of the respondents in the U.S. believe that reducing the consumption of meat or dairy products makes a high contribution to climate protection. Financial advantages associated with the climate protection activities are rated remarkably lower (compared to the other climate protection activities) for using energy from renewable sources (only in Germany) and reducing the consumption of meat or dairy products (in both countries) and highest for buying energy-efficient appliances (in the U.S.) and saving energy (in Germany). Accordingly, a large proportion of the respondents is willing to buy energy-efficient appliances (84 percent in Germany and 78 percent in the U.S.) and save energy at home (87 percent in Germany and 81 percent in the U.S.) in the future, while reducing the number of flights (36 percent in Germany and 47 percent in the U.S.) and reducing the consumption of meat or dairy products (50 percent in Germany and 42 percent in the U.S.) are the climate protection activities with the lowest average stated willingness. It is also noticeable that German respondents exhibit higher average values for the NEP scale and the warm glow indicator, while U.S. respondents are slightly older, higher educated and have more children compared to German respondents.[13]

For our microeconometric analysis of the general propensity to take the clean consumption alternatives in the future, we stack our data over all seven activities such that our dependent variable comprises the responses for all of the seven climate protection activities. Seven binary variables identify each clean consumption alternative. This arrangement of our data allows us to apply random effects binary probit models and thereby to control for unobserved heterogeneity. This approach incorporates individual-specific random effects which are constant over the clean consumption alternatives and are assumed to be uncorrelated with the explanatory variables. For both samples, a Hausman test fails to detect systematic differences in the coefficients of a fixed and random effects specification and a likelihood ratio test rejects the null hypothesis of no unobserved heterogeneity which justifies the application of random effects binary probit models.[14] In order to check the robustness of our results when not controlling for unobserved heterogeneity, we also estimate pooled binary probit models (with stacked data) and single binary probit models for each clean consumption alternative (with

[13] For our econometric analyses all missing values are dropped. Nonetheless, descriptive statistics for individuals included in our econometric analyses only differ slightly from the descriptive statistics of the whole samples.
[14] Test results are available upon request.

unstacked data). The results are qualitatively very similar to the parameter estimates obtained from the random effects probit models.[15]

To investigate further implications of our theoretical predictions, we include several two-way and three-way interaction terms in our models. We estimate average interaction effects across all observations following the approach of Ai and Norton (2003), Norton et al. (2004) as well as Cornelißen and Sonderhof (2009).[16] Specifically, we relate to the cases (A.2), (B.2), and (B.3).

Firstly, with offsetting being more effective in providing the public characteristic ($\beta_i^o > \beta_i^c$) and the clean consumption alternative being more effective in providing the private characteristic ($\alpha_i^c \geq 1$), offsetting and the climate protection activity might be used complementarily. To test this case (A.2) we include the interaction term *offsetting* × *high contribution of offsetting* × *financial advantages of clean good* (besides the three two-way interaction terms of the interacted variables).

Secondly, in case (B.2), where offsetting has an intermediate effectiveness in providing the public characteristic ($\beta_i^c \leq \beta_i^o \leq \frac{\beta_i^c}{1-\alpha_i^c}$), offsetting and the clean good can be complements if environmental preferences are high enough. In order to test this case, we include the interaction term *offsetting past* × *intermediate effectiveness of offsetting*[17]. The new binary variable *intermediate effectiveness of offsetting* is also included as single explanatory variable and indicates that respondents rated the contribution of offsetting to climate protection as being equal or higher compared to the contribution of the clean consumption alternatives and at the same time believe that a certain climate protection activity provides neither financial advantages nor financial disadvantages or rather financial disadvantages.

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[15] For the pooled binary probit models with the stacked data and the single binary probit models for each clean consumption alternative separately, we consider robust estimations of the standard deviation of the parameter estimates. For random effects binary probit models with the stacked data, the robustness of the estimations of the standard deviation of the parameter estimates was tested using bootstrapping methods, but the results hardly differ from those reported in Table 4 and thus are not reported.

[16] We add interaction terms to the initial model. We estimate eight different models to separately obtain the eight interaction effects. These models also contain the interacted variables as single explanatory variables and, in case of three-way interaction terms, the three two-way interaction terms of the interacted variables. Estimation results are qualitatively very similar in the models with (results are available upon request) and without interaction terms. A joint estimation of all interaction terms fails due to collinearity.

[17] Due to potential problems of multicollinearity, in the new model specification with the variable *intermediate effectiveness of offsetting*, the variables *high contribution of offsetting*, *high contribution of clean good*, and *financial advantages of clean good* are dropped from the initial econometric model. When *ineffective clean good* is included, the variables *high contribution of clean good* and *financial advantages of clean good* are dropped since they are captured by the new variable.

Finally, we include the three-way interaction term *offsetting* × *high contribution of offsetting* × *ineffective clean good*[17], which reflects case (B.3) where the clean consumption alternative is predicted to be substituted by offsetting and the dirty alternative if $\beta_i^o > \frac{\beta_i^c}{1-\alpha_i^c}$. For this interaction term, we construct a new binary variable *ineffective clean good* (also included as single explanatory variable) which indicates that the respondent perceives the climate protection activity to contribute rather little or very little to climate protection and provides rather financial disadvantages. In addition, we estimate the average effects across all observations of the two-way interactions of *offsetting* with *NEP scale*, *warm glow indicator*, *financial advantages of clean good,* and *high contribution of offsetting*.

4. Estimation results

Our discussion of the empirical findings focuses on the estimation results from the random effects probit models with stacked data reported in Table 4. These results are robust when using pooled binary probit models with stacked data (Table 4) or single binary probit models for each climate protection activity (Tables 5 and 6).[18] Including the binary variables that identify the clean consumption alternative allows us to examine differences in the willingness to take these alternatives. Using *reducing the consumption of meat or dairy products* as the base activity, we find that only the willingness of U.S. respondents to reduce the number of flights is significantly smaller than the willingness to reduce the consumption of meat or dairy products, while the willingness is significantly higher for all other climate protection activities in both countries.

Surprisingly, only a few socio-economic and socio-demographic characteristics influence the willingness to use cleaner consumption alternatives. In Germany, females and respondents living in Western Germany show a significantly higher propensity, and U.S. respondents living in the Western part of the U.S. are significantly less likely to take one of the climate protection activities compared to respondents living in the South.

For Germany and the U.S., our estimation results suggest a strong positive relationship between *offsetting* and the willingness to use one of the clean consumption alternatives.[19] In both countries, this willingness is significantly driven by environmental preferences measured

[18] Our results are very robust using random effects logit models and also to alternative model specifications regarding the inclusion of different control variables.

[19] Since flying is the most common context for compensating carbon emissions, it could be expected that offsetting is a substitute to reducing the number of flights. Surprisingly, however, *offsetting* is also complementary to *reducing flights* in both countries (statistically significant at the 1% level).

by the variables *NEP scale* and *warm glow indicator* (significantly positive at the 1% level for the majority of clean consumption alternatives). In Germany, *high contribution of clean good* (corresponding to large β_i^c in the theoretical model) also plays a very important role for choosing the clean consumption alternatives, while we detect no such impact for U.S. respondents. Our estimation results also reveal a highly significant positive effect of perceived financial advantages associated with the climate protection activity, which is in line with our theoretical prediction that for $\alpha_i^c > 1$ the clean good dominates the dirty alternative (cases (A.1) and (A.2)).[20] In the U.S., a perceived high contribution of offsetting to climate protection (reflected by β_i^o in the model) significantly reduces the willingness to use the clean consumption alternatives in the future. This finding is consistent with our predictions for highly effective offsetting (case (B.3)) where individuals were predicted to revert to the dirty alternative.

Further implications of our theoretical predictions are reflected by the two-way and three-way interaction terms described in Section 3 and Tables 7 and 8 report the estimates (including z-statistics) of average interaction effects as well as average discrete probability effects of the interacted variables which are needed for the interpretation of the interaction effects.[21] For choosing the clean consumption alternatives *buying energy efficient appliances, saving energy at home*, and *buying a car with lower fuel consumption*, the significantly negative interaction effect of *offsetting* and *high contribution of offsetting* for German respondents confirms the prediction that the clean consumption is dominated by the dirty alternative and offsetting if the perceived effectiveness of offsetting is large (case (B.3) and possibly (B.2), depending on substitutability).

For Germany, the average effects of the three-way interactions reflecting cases (A.2) and (B.3) are on average not significantly different from zero. In contrast, the average two-way interaction effect of *offsetting* with *intermediate effectiveness of offsetting* (corresponding to case (B.2) in the model) is positive and highly significant. This finding implies that the complementary relationship between offsetting and other climate protection activities gets even larger if offsetting has an intermediate effectiveness in providing the public good.

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[20] In the U.S., financial advantages associated with an activity have significantly positive effects on all of the seven climate protection activities (statistically significant at the 1% level).

[21] Two-way interaction effects capture how one variable affects the impact of the other variable on the binary dependent variable, i.e. the effect of a discrete change in one variable on the discrete probability effect of the other variable. Three-way interaction effects reflect how one variable affects the interaction effect of the two other dummy variables on the binary dependent variable, i.e. the discrete change in one variable on the interaction effect of the other two variables.

For U.S. respondents, the two average three-way interaction effects and the average two-way interaction effect of *offsetting* with *intermediate effectiveness of offsetting* are highly significant. The interaction effect of *offsetting* with *high contribution of offsetting* and *financial advantages of clean good* is significantly positive. While the negative interaction effect of *offsetting* and *financial advantages of clean good* reduces the complementary relationship between offsetting and other climate protection, the estimation result for the three-way interaction term with *high contribution of offsetting* confirms that offsetting and the clean consumption alternatives might be complementarily used if offsetting is perceived to be highly effective in providing the public good and the clean consumption alternative being highly effective in providing the private characteristic (case (A.2)). Similar to the results for German respondents, the significantly positive interaction effect of *offsetting* with *intermediate effectiveness of offsetting* reflects case (B.2) where offsetting with some intermediate effectiveness may also increase the consumption of the impure public good. For case (B.3), our estimation results reveal a significantly negative interaction effect of *offsetting* with *high contribution of offsetting* and *ineffective clean good*. In this case, the high estimated average interaction effect inverts the complementary relationship between offsetting and the climate protection activities. This finding implies that the clean consumption alternatives may be substituted by offsetting and the dirty consumption alternatives if offsetting is perceived to be highly effective in providing the public good, while the clean consumption alternatives are perceived to be relatively ineffective in providing the private characteristic.

In addition, we find significantly negative interaction effects between *offsetting* and *NEP scale* (only for U.S. respondents) as well as *offsetting* and *warm glow indicator* (in both countries). Higher environmental preferences therefore reduce the complementary relation between offsetting and climate protection activities, but only the interaction effect with *warm glow indicator* seems be large enough to convert it to a substitution effect. This finding is consistent with the idea of moral balancing. Consumption of clean alternatives in the past is substantially higher for individuals with higher environmental preferences, such that offsetting is not needed to regain moral balance but gives these individuals a license to choose dirty consumption alternatives in the future. As mentioned in the introduction, Kotchen and Moore (2008) find a similar result in their study of the green-electricity market. They argue that conservationists already internalized negative externalities by reducing their use of conventional energy before participating in green-energy programs, but that these individuals may also be less flexible in their energy demand due to these voluntary restraints.

Altogether our empirical findings confirm the predictions from our theoretical model that offsetting and climate protection activities may be substitutes or complementarily used depending on environmental preferences and the effectiveness of offsetting in providing climate protection relative to the effectiveness of clean and dirty consumption alternative.

5. Summary and conclusions

This paper provides theoretical and empirical insights on the extent to which the availability of carbon offsetting may substitute the individual use of other carbon-reducing measures. Our theoretical predictions, based on a theory that explicitly considers the consumption patterns of dirty vs. clean(er) consumption alternatives in interaction with offsetting, demonstrate a potentially ambiguous impact of offsetting options on the consumption of the impure public good, i.e. the clean alternative, but also predicts its full crowding out when offsets are highly effective in generating the public good.

Relying on data from representative surveys among more than 2000 participants from Germany and the U.S., our empirical results confirm the theoretical predictions that offsetting and climate protection activities may be both, substitutes or complements. Our findings suggest that offsetting may substitute certain clean consumption alternatives if individuals lay a sufficiently large weight on environmental preference or if offsetting is relatively effective in providing the public good climate protection, while offsetting and clean consumption alternatives seem to be rather complementary if offsetting is perceived to have some intermediate effectiveness.

One shortcoming of our analysis, however, is that empirical evidence is based on the stated willingness to take climate protection activities in the future. Future research should investigate whether our behavioral findings are robust using data on revealed preferences or panel data with time references for offsetting purchase and the consumption of cleaner alternatives, and whether the analyses in this paper can be applied to other fields of private provisions of impure public goods and charitable giving like volunteer labor or blood and organ donations.

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Appendix

Table 1: Description of dependent variables

Variables	Description
Buying energy-efficient appliances	1 if the respondent plans to buy energy-efficient appliances in the future, 0 otherwise.
Saving energy at home	1 if the respondent plans to take actions to save energy at home in the future, 0 otherwise.
Buying a car with lower fuel consumption	1 if the respondent plans to buy a car with lower fuel consumption in the future, 0 otherwise.
Reducing meat or dairy products	1 if the respondent plans to reduce the consumption of meat or dairy products in the future, 0 otherwise.
Reducing car use	1 if the respondent plans to reduce car use in the future, 0 otherwise.
Reducing flights	1 if the respondent plans to reduce the number of flights in the future, 0 otherwise.
Using energy from renewable sources	1 if the respondent plans to use or purchase energy from renewable sources in the future, 0 otherwise.

Table 2: Description of explanatory variables

Variables	Description
Offsetting	1 if the respondent already engaged in offsetting in the past, 0 otherwise.
High contribution of offsetting	1 if the respondent believes offsetting contributes rather a lot or a lot to climate protection, 0 otherwise. The underlying question is "how effective is CO2 offsetting in protecting the climate?" with the five ordered response categories: "Very ineffective", "rather ineffective", "neither effective nor ineffective", "rather effective", and "very effective".
High contribution of clean good	1 if the respondent believes that a certain climate protection activity contributes rather a lot or a lot to climate protection, 0 otherwise. The underlying question is "how much do you believe the following measures contribute to climate protection" with the five ordered response categories: "Very little", "rather little", "neither a little nor a lot", "rather a lot", and a lot".
Financial advantages	1 if the respondent believes that a certain climate protection activity provides rather financial advantages for her personally, 0 otherwise. The underlying question is "in your opinion, do the following measures provide rather financial advantages (e.g., saving money, financial gains) or rather financial disadvantages (e.g., costs) for you personally" with the three ordered response categories: "Rather financial disadvantages", "neither financial advantages nor disadvantages", and "rather financial advantages".
Warm glow indicator	1 if the respondent agreed rather strongly or very strongly to the statement "it makes me feel good to contribute to climate protection" or to the statement "I feel responsible for making a contribution to climate protection", 0 otherwise. The underlying question is "how strongly do you agree to the following statement" with the five ordered response categories "very weakly", "rather weakly", "neither weakly nor strongly", "rather strongly", and "very strongly".

Table 2: Description of explanatory variables (continued)

Variables	Description
NEP scale	Additive indicator using the following six items from the NEP scale: - "humans have the right to modify the natural environment to suit their needs" - "humans are severely abusing the planet", - "plants and animals have the same right to exist as humans", - "nature is strong enough to cope with the impacts of modern industrial nations", - "humans were meant to rule over the rest of nature", - "the balance of nature is very delicate and easily upset". The underlying question is "how strongly do you agree to the following statement" with the five ordered response categories "very weakly", "rather weakly", "neither weakly nor strongly", "rather strongly", and "very strongly". The variable is designed by constructing dummy variables that take the value one if the respondent agrees to the respective statement rather or very strongly (in the case of positively keying items) or rather or very weakly (in the case of negatively keying items), respectively, and adding up the six dummy variables. Accordingly, the variable takes values from 0 to 6.
Age	Age of the respondent in years.
Female	1 if the respondent is a woman, 0 otherwise.
High household income	1 if the household net income of the respondent is above median category of the sample (i.e. at least € 3,000 in Germany and $ 4,000 in the U.S.), 0 otherwise.
Highly educated	1 if the respondent's highest level of education is at least secondary (Abitur in Germany, College degree in the U.S.), 0 otherwise.
Number of own children	Number of own children of the respondent.
Western Germany	1 if the respondent lives in Western Germany, 0 otherwise.
Northeast (Midwest, West)	1 if the respondent lives in the Northeast (Midwest, West) of the USA, 0 otherwise.
Financial disadvantages	1 if the respondent believes that a certain climate protection activity provides rather financial disadvantages for her personally, 0 otherwise. Underlying question and response categories are described for the variable financial advantages of clean good.
Ineffective clean good	1 if the respondent perceives the climate protection activity to contribute rather little or very little to climate protection and at the same time provides rather financial disadvantages for her personally, 0 otherwise. Underlying questions and response categories are described for the variables high contribution of clean good and financial advantages of clean good.
Intermediate effectiveness of offsetting	1 if the respondent rated the contribution of offsetting to climate protection as being equal or higher compared to the contribution of the climate protection activities to climate protection and at the same time believes that a certain activity provides neither financial advantages nor financial disadvantages for her personally, 0 otherwise. Underlying questions and response categories are described for the variables high contribution of offsetting, high contribution of clean good and financial advantages of clean good.

Table 3: Descriptive statistics of dependent and explanatory variables for overall 1,005 observations in Germany and 1,010 observations in the U.S.

	Germany			U.S.		
Variables	Number of observations	Mean	Standard deviation	Number of observations	Mean	Standard deviation
Offsetting	788	0.11	0.31	750	0.14	0.35
High contribution of offsetting	892	0.54	0.50	778	0.49	0.50
Buying energy-efficient appliances	969	0.84	0.36	952	0.78	0.41
financial advantages	956	0.62	0.49	914	0.73	0.44
high contribution	966	0.61	0.49	926	0.63	0.48
Saving energy at home	973	0.87	0.34	965	0.81	0.39
financial advantages	956	0.81	0.39	919	0.76	0.43
high contribution	964	0.61	0.49	924	0.61	0.49
Buying a car with lower fuel consumption	929	0.71	0.45	915	0.67	0.47
financial advantages	912	0.61	0.49	877	0.66	0.47
high contribution	956	0.63	0.48	918	0.61	0.49
Reducing meat or dairy products	964	0.50	0.50	939	0.42	0.49
financial advantages	897	0.37	0.48	833	0.39	0.49
high contribution	948	0.35	0.48	847	0.25	0.43
Reducing car use	805	0.62	0.49	739	0.62	0.49
financial advantages	928	0.62	0.48	896	0.64	0.48
high contribution	958	0.63	0.48	925	0.59	0.49
Reducing flights	547	0.36	0.48	371	0.47	0.50
financial advantages	834	0.56	0.50	805	0.55	0.50
high contribution	944	0.62	0.49	854	0.50	0.50
Using energy from renewable sources	942	0.62	0.49	890	0.50	0.50
financial advantages	879	0.29	0.45	813	0.50	0.50
high contribution	949	0.67	0.47	875	0.60	0.49
Warm glow indicator	957	0.66	0.47	934	0.60	0.49
NEP scale	967	4.04	1.82	978	3.03	1.88
Age	1,005	41.13	12.52	1,010	48.51	14.46
Female	1,005	0.49	0.50	1,010	0.53	0.50
High household income	822	0.41	0.49	864	0.37	0.48
Highly educated	1,000	0.55	0.50	1,006	0.68	0.47
Number of own children	1,005	0.95	1.12	1,010	1.32	1.39
Western Germany	1,005	0.79	0.41			
Northeast				1,010	0.20	0.40
Midwest				1,010	0.23	0.42
West				1,010	0.22	0.41

Table 4: ML estimates (z-statistics) of parameters in the random effects and pooled binary probit models in Germany and the U.S., dependent variable: stated willingness to take one of the seven climate protection activities

Explanatory variables	Germany		U.S.	
	Random effects binary probit model	Pooled binary probit model	Random effects binary probit model	Pooled binary probit model
Buying energy-efficient appliances	1.17***	0.92***	1.22***	0.90***
	(0.10)	(0.09)	(0.11)	(0.09)
Saving energy at home	1.21***	0.96***	1.26***	0.92***
	(0.11)	(0.09)	(0.11)	(0.09)
Buying a car with lower fuel consumption	0.57***	0.47***	0.79***	0.59***
	(0.09)	(0.08)	(0.11)	(0.09)
Using energy from renewable sources	0.33***	0.27***	0.33***	0.27***
	(0.09)	(0.08)	(0.10)	(0.09)
Reducing car use	0.17*	0.17**	0.52***	0.39***
	(0.09)	(0.08)	(0.11)	(0.09)
Reducing the number of flights	-0.66***	-0.49***	-0.06	-0.04
	(0.11)	(0.09)	(0.13)	(0.11)
Offsetting	0.44***	0.32***	0.68***	0.48***
	(0.15)	(0.08)	(0.16)	(0.07)
High contribution of offsetting	-0.09	-0.06	-0.38***	-0.27***
	(0.09)	(0.05)	(0.13)	(0.06)
High contribution of clean good	0.40***	0.29***	-0.04	-0.08
	(0.07)	(0.05)	(0.09)	(0.06)
Financial advantages of clean good	0.39***	0.27***	0.75***	0.60***
	(0.06)	(0.05)	(0.08)	(0.05)
Warm glow indicator	0.46***	0.35***	0.60***	0.43***
	(0.11)	(0.06)	(0.13)	(0.06)
NEP scale	0.07***	0.06***	0.13***	0.09***
	(0.03)	(0.01)	(0.03)	(0.02)
Age	0.00	0.00	-0.00	-0.00*
	(0.00)	(0.00)	(0.00)	(0.00)
Female	0.16*	0.10**	0.14	0.08
	(0.09)	(0.05)	(0.11)	(0.05)
Number of own children	-0.01	-0.01	0.04	0.04*
	(0.04)	(0.02)	(0.04)	(0.02)
High household income	0.09	0.07	0.12	0.07
	(0.09)	(0.05)	(0.12)	(0.05)
Highly educated	0.05	0.02	0.18	0.13**
	(0.09)	(0.05)	(0.12)	(0.06)
Western Germany	0.24**	0.19***		
	(0.11)	(0.06)		
West			-0.48***	-0.33***
			(0.15)	(0.07)
Northeast			-0.20	-0.15**
			(0.15)	(0.07)
Midwest			-0.11	-0.07
			(0.14)	(0.07)
Constant	-1.31***	-0.95***	-1.12***	-0.78***
	(0.24)	(0.13)	(0.26)	(0.13)
Number of observations	3,606	3,606	3,135	3,135
Number of respondents	585		526	

* (**, ***) means that the appropriate parameter is different from zero at the 10% (5%, 1%) significance level.

Table 5: ML estimates (z-statistics) of parameters in the binary probit models in Germany, dependent variables: stated willingness to take one of the seven climate protection activities

Explanatory variables	Buying energy-efficient appliances	Saving energy at home	Reducing meat or dairy products	Using energy from renewable sources	Buying a car with lower fuel consumption	Reducing car use	Reducing flights
Offsetting	0.17	-0.18	0.38**	0.47**	0.58**	0.32	0.51**
	(0.77)	(-0.85)	(1.98)	(2.28)	(2.51)	(1.49)	(2.40)
High contribution of offsetting	0.08	-0.14	-0.15	0.00	-0.13	0.04	-0.01
	(0.57)	(-0.97)	(-1.28)	(0.02)	(-1.02)	(0.28)	(-0.09)
High contribution of clean good	0.09	0.25*	0.67***	0.31**	0.03	0.22	0.47***
	(0.63)	(1.76)	(5.27)	(2.30)	(0.20)	(1.55)	(2.89)
Financial advantages of clean good	-0.00	0.34**	0.36***	0.16	0.35***	0.45***	0.25
	(-0.00)	(2.08)	(2.93)	(1.23)	(2.80)	(3.48)	(1.60)
Warm glow indicator	0.15	-0.12	0.42***	0.51***	0.50***	0.51***	0.35*
	(1.00)	(-0.76)	(3.05)	(3.68)	(3.42)	(3.51)	(1.85)
NEP scale	0.07*	0.15***	0.06*	0.06*	0.03	0.07*	-0.02
	(1.84)	(3.48)	(1.65)	(1.74)	(0.71)	(1.94)	(-0.38)
Age	0.00	0.00	0.01	-0.01**	0.01	0.01*	0.00
	(0.71)	(0.10)	(1.21)	(-2.42)	(1.19)	(1.90)	(0.36)
Female	0.03	0.13	0.39***	0.06	-0.07	0.02	0.04
	(0.20)	(0.96)	(3.33)	(0.52)	(-0.56)	(0.18)	(0.29)
Number of own children	-0.04	-0.05	-0.03	-0.00	-0.04	-0.03	0.21***
	(-0.66)	(-0.82)	(-0.53)	(-0.06)	(-0.73)	(-0.48)	(2.78)
High household income	0.00	0.01	0.07	0.15	0.23*	-0.01	-0.10
	(0.02)	(0.10)	(0.56)	(1.19)	(1.87)	(-0.06)	(-0.67)
Highly educated	-0.00	0.15	-0.03	0.13	-0.17	0.04	-0.09
	(-0.03)	(1.09)	(-0.27)	(1.05)	(-1.36)	(0.34)	(-0.53)
Western Germany	0.13	0.12	0.24	0.35**	0.22	0.16	0.12
	(0.86)	(0.78)	(1.64)	(2.52)	(1.52)	(1.08)	(0.66)
Constant	0.32	0.15	-1.40***	-0.44	-0.35	-1.30***	-1.23***
	(0.96)	(0.45)	(-4.50)	(-1.48)	(-1.14)	(-4.09)	(-3.06)
Number of respondents	581	579	548	537	546	489	326

* (**, ***) means that the appropriate parameter is different from zero at the 10% (5%, 1%) significance level.

Table 6: ML estimates (z-statistics) of parameters in the binary probit models in the U.S., dependent variables: stated willingness to take one of the seven climate protection activities

Variables	Buying energy-efficient appliances	Saving energy at home	Reducing meat or dairy products	Using energy from renewable sources	Buying a car with lower fuel con-sumption	Reducing car use	Reducing flights
Offsetting	0.08	0.15	0.47***	0.51***	0.37**	0.81***	1.06***
	(0.39)	(0.73)	(2.63)	(2.76)	(1.99)	(3.89)	(4.40)
High contribution of offsetting	-0.30	-0.33*	-0.11	-0.19	-0.26*	-0.48***	-0.30
	(-1.63)	(-1.77)	(-0.77)	(-1.28)	(-1.74)	(-2.93)	(-1.36)
High contribution of clean good	-0.59***	-0.11	0.17	0.02	-0.19	-0.12	0.20
	(-3.50)	(-0.66)	(1.04)	(0.10)	(-1.23)	(-0.71)	(0.99)
Financial advantages of clean good	0.72***	0.65***	0.58***	0.50***	0.52***	0.51***	0.53***
	(4.50)	(4.21)	(4.08)	(3.35)	(3.87)	(3.41)	(2.68)
Warm glow indicator	0.64***	0.43**	0.32**	0.67***	0.24	0.55***	0.32
	(3.69)	(2.44)	(2.10)	(4.09)	(1.55)	(3.18)	(1.34)
NEP scale	0.15***	0.12***	0.05	0.10**	0.15***	0.11***	-0.04
	(3.48)	(2.90)	(1.37)	(2.45)	(3.81)	(2.78)	(-0.66)
Age	-0.00	0.00	-0.01	-0.02***	0.01	-0.00	-0.00
	(-0.21)	(0.11)	(-1.06)	(-4.07)	(1.07)	(-0.02)	(-0.03)
Female	0.06	0.25*	0.21	-0.06	0.01	0.20	-0.14
	(0.39)	(1.77)	(1.56)	(-0.45)	(0.08)	(1.40)	(-0.67)
Number of own children	0.09	0.09	0.01	0.05	-0.01	0.03	-0.00
	(1.52)	(1.58)	(0.28)	(1.04)	(-0.28)	(0.66)	(-0.02)
High household income	0.21	-0.06	0.10	0.18	0.33**	-0.17	-0.15
	(1.40)	(-0.43)	(0.79)	(1.35)	(2.44)	(-1.24)	(-0.75)
Highly educated	0.01	0.08	-0.03	0.02	0.32**	0.33**	0.12
	(0.07)	(0.50)	(-0.18)	(0.11)	(2.31)	(2.19)	(0.46)
West	-0.57***	-0.61***	-0.14	-0.20	-0.33*	-0.33*	-0.27
	(-3.17)	(-3.39)	(-0.81)	(-1.12)	(-1.95)	(-1.76)	(-1.09)
Northeast	-0.15	-0.33*	-0.07	-0.02	-0.23	-0.26	-0.20
	(-0.74)	(-1.66)	(-0.38)	(-0.09)	(-1.31)	(-1.36)	(-0.74)
Midwest	-0.16	-0.14	-0.16	-0.01	0.04	-0.21	0.03
	(-0.88)	(-0.80)	(-0.98)	(-0.03)	(0.21)	(-1.22)	(0.12)
Constant	0.10	0.03	-0.61**	0.06	-0.68**	-0.57*	-0.48
	(0.33)	(0.10)	(-2.07)	(0.22)	(-2.42)	(-1.86)	(-1.13)
Number of respondents	508	519	476	470	500	434	228

* (**, ***) means that the appropriate parameter is different from zero at the 10% (5%, 1%) significance level.

Table 7: Estimates (z-statistics) of average discrete probability effects and average interaction effects in Germany[i]

Variables and interaction terms	Random effects binary probit models	Pooled binary probit model	Binary probit models						
	Stacked data		Buying energy-efficient appliances	Saving energy at home	Reducing meat or dairy products	Using energy from renewable sources	Buying a car with lower fuel consumption	Reducing car use	Reducing flights
Offsetting	0.12*** (3.25)	0.09*** (4.36)			0.13** (2.04)	0.15** (2.52)	0.15*** (3.11)		0.18** (2.38)
High contribution of offsetting	-0.02 (-0.90)	-0.02 (-1.29)							
High contribution of clean good	0.12*** (3.39)	0.09*** (5.48)		0.05* (1.71)	0.24*** (5.36)	0.11** (2.24)			0.16*** (2.93)
Financial advantages of clean good	0.11*** (3.45)	0.08*** (5.18)		0.07* (1.88)	0.13*** (2.94)		0.11*** (2.77)	0.16*** (3.45)	
NEP scale	0.01 (1.47)	0.02*** (4.07)	0.02* (1.84)	0.03*** (3.47)	0.02* (1.67)	0.02* (1.75)		0.02* (1.96)	
Warm glow indicator	0.12*** (3.46)	0.11*** (5.99)			0.15*** (3.01)	0.18*** (3.58)	0.16*** (3.29)	0.18*** (3.39)	0.12* (1.89)
Offsetting × NEP scale	-0.02 (-1.04)	-0.02* (-1.87)							
Offsetting × warm glow indicator	-0.18** (-2.21)	-0.16*** (-3.42)	-0.19** (-2.31)		-0.26* (-1.86)			-0.39*** (-3.09)	
Offsetting × high contribution of offsetting	-0.08 (-1.18)	-0.10** (-2.34)	-0.17** (2.08)	-0.17* (-1.82)			-0.18* (-1.87)		
Offsetting × financial advantages of clean good	-0.09* (-1.79)	-0.13*** (-3.14)						-0.24* (-1.92)	
Offsetting × high contribution of offsetting × financial advantages of clean good	0.06 (0.63)	0.05 (0.33)	-	-	-	-	-	-	-
Offsetting × intermediate effectiveness of offsetting	0.10*** (2.65)	0.13*** (3.12)							0.23* (1.80)
Offsetting × high contribution of offsetting × ineffective clean good	-0.22 (-0.65)	-0.30 (-0.94)	-	-	-	-	-	-	-

* (**, ***) means that the appropriate effect is different from zero at the 10% (5%, 1%) significance level.

Table 8: Estimates (z-statistics) of average discrete probability effects and average interaction effects in the U.S.[i]

Variables and interaction terms	Random effects binary probit models	Pooled binary probit model	Binary probit models						
	Stacked data		Buying energy-efficient appliances	Saving energy at home	Reducing meat or dairy products	Using energy from renewable sources	Buying a car with lower fuel consumption	Reducing car use	Reducing flights
Offsetting	0.18***	0.14***			0.17***	0.16***	0.11**	0.24***	0.37***
	(4.19)	(7.22)			(2.63)	(2.85)	(2.16)	(4.74)	(5.15)
High contribution of offsetting	-0.10***	-0.08***	-0.07*	-0.08*			-0.08*	-0.15***	
	(-2.90)	(-4.74)	(-1.69)	(-1.84)			(-1.78)	(-3.15)	
High contribution of clean good	-0.01	-0.02	-0.13***						
	(-0.31)	(-1.26)	(-3.78)						
Financial advantages of clean good	0.22***	0.20***	0.20***	0.17***	0.21***	0.17***	0.17***	0.17***	0.18***
	(9.48)	(10.62)	(4.25)	(3.83)	(4.02)	(3.32)	(3.81)	(3.41)	(2.76)
NEP scale	0.04***	0.03***	0.04***	0.03***		0.03**	0.05***	0.04***	-0.01
	(3.68)	(6.10)	(3.59)	(3.00)		(2.49)	(3.95)	(2.85)	(-0.66)
Warm glow indicator	0.16***	0.14***	0.16***	0.11**	0.11**	0.24***		0.19***	
	(3.86)	(6.71)	(3.60)	(2.35)	(2.07)	(4.03)		(3.19)	
Offsetting × NEP scale	-0.05*	-0.04***			-0.07**		-0.05**	-0.05*	
	(-1.91)	(-3.33)			(-1.91)		(-2.13)	(-1.90)	
Offsetting × warm glow indicator	-0.25***	-0.23***		-0.30***		-0.27**		-0.26**	-0.32**
	(-3.53)	(-5.43)		(-2.87)		(-2.09)		(-2.56)	(-2.41)
Offsetting × high contribution of offsetting	-0.04	-0.04				-0.22*			
	(-1.18)	(-0.77)				(-1.76)			
Offsetting × financial advantages of clean good	-0.15***	-0.11***						-0.20**	-0.22*
	(-2.62)	(-2.91)						(-2.03)	(-1.68)
Offsetting × high contribution of offsetting × financial advantages of clean good	0.34***	0.45**	-	-	-	-	-	-	-
	(3.42)	(2.53)							
Offsetting × intermediate effectiveness of Offsetting	0.16**	0.12***						0.21**	
	(2.35)	(2.99)						(2.02)	
Offsetting × high contribution of offsetting × ineffective clean good	-0.48***	-0.43**	-	-	-	-	-	-	-
	(-3.37)	(-2.36)							

* (**, ***) means that the appropriate effect is different from zero at the 10% (5%, 1%) significance level.

[i] For the single binary probit models, only statistically significant interaction effects are reported. Interaction effects for three-way interaction terms can only be estimated with stacked data. Using unstacked data, the underlying group of respondents is too small to obtain robust and meaningful results from the single binary probit models for each climate protection activity.

Discrete probability effects are estimated from the initial model without interaction terms. The estimated effects are very similar in the models with and without interaction terms.

For estimating the interaction effects, we add interaction terms to the initial model. We estimate eight different models to separately obtain the eight interaction effects. These models also contain the interacted variables as single explanatory variables and, in case of three-way interaction terms, the three two-way interaction terms of the interacted variables. A joint estimation of all interaction terms fails due to collinearity.