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Do Social Norms Matter to Energy Saving Behavior? Endogenous Social and Correlated Effects

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Abstract

Social norms have received growing attention as a potential driver for pro-environmental behavior, partly due to ample evidence based on survey data. Using data from a Japanese household survey on energy saving behavior, we estimate a structural model of social interactions that account for methodological issues inherent in survey data, namely: simultaneity, common shocks and nonrandom group selection. We find that the influence of social norms on energy saving behavior is small or insignificant, while estimates from standard methods in the literature are found to be large and highly significant. Our results suggest that evidence in previous survey-based studies may reflect correlation in unobserved characteristics between members in a group, not the influence of social norms.

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Do Social Norms Matter to Energy Saving Behavior? Endogenous Social and Correlated Effects[1]

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Abstract

Social norms have received growing attention as a potential driver for pro-environmental behavior, partly due to ample evidence based on survey data. Using data from a Japanese household survey on energy saving behavior, we estimate a structural model of social interactions that account for methodological issues inherent in survey data, namely: simultaneity, common shocks and nonrandom group selection. We find that the influence of social norms on energy saving behavior is small or insignificant, while estimates from standard methods in the literature are found to be large and highly significant. Our results suggest that evidence in previous survey-based studies may reflect correlation in unobserved characteristics between members in a group, not the influence of social norms.

JEL Codes: Q40, Q50

Key Words: Energy Savings, Social Norms, Structural Estimation

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1. Introduction

Many environmental issues, such as global warming, overflowing landfills and water scarcity, are primarily, if not exclusively, caused by human behavior (Gardner and Stern, 2002; Lehman and Geller, 2004; Vlek and Steg, 2007). Although new technologies mitigate environmental impacts from human behavior, efficiency gains from technological progress may not be enough to achieve environmental sustainability. Changes in human behavior, in particular, increasing pro-environmental behavior, seem to be essential (Steg and Vlek, 2009).

To encourage pro-environmental behavior, it is important to understand what drives or prevents such behavior. For this purpose, many cross-sectional survey studies have been conducted, mainly in the field of social psychology. One of the intriguing results in the literature is that an individual's pro-environmental behavior is strongly and positively associated with the common behavior of others in his/her social group, i.e., *social norms* (e.g., Barr, 2007; Corral-Verdugo et al., 2002; Dahlstrand and Biel, 1997; Hage et al., 2009; Nolan et al., 2008; Oskamp et al., 1991).

Loosely speaking, those results are obtained by regressing individual's pro-environmental action or intention on the perception of common action in his/her social group (i.e., a social norm variable), as well as a set of control variables. If the coefficient on the social norm variable is found to be positive and significant, it is interpreted in the literature as evidence that social norms influence individuals' pro-environmental action/intention.

Despite providing insights into the relationship between pro-environmental behaviors of individuals and their social groups, results in those survey studies may not be interpreted as causal. This is because while they treat social norm variables as exogenous, the variables are potentially endogenous. As pointed out in the literature on the identification and estimation of social interactions (e.g., Brock and Durlauf, 2001; Krauth, 2006; Manski, 1993; Manski, 2000; Moffit, 2001), there are at least two sources of endogeneity. The first is simultaneity. If an individual's behavior is directly influenced by that of members in his/her group, the individual's behavior also influences the group members' behavior. The second source is correlation in unobserved characteristics among members in a social group. If an individual's unobserved characteristics are correlated with those of the group members, the behavior of the members (and hence, the social norm variable) becomes endogenous. Correlation in unobserved characteristics arises due to common unobserved characteristics such as common institutional environments, and/or nonrandom group formation.

This study examines the relationship between social norms and pro-environmental behavior, using survey data on Japanese households with regard to their energy saving behavior. Unlike previous studies in the literature, we attempt to deal with simultaneity and between-peer correlation in unobserved characteristics by using the approach that Krauth (2006) proposed. This approach estimates a structural model of social interactions where an individual's utility is allowed to depend on the actions of others in his/her social group. A game theoretic framework is used to determine which combinations of choices are possible equilibria; once they are determined, probabilities of observed choices are computed. Identification is achieved by restricting between-peer correlation in unobservables to equal between-peer correlation in observables, that is, the assumption in the spirit of Altonji et al. (2005).

Unlike reduced-form methods used in the literature, this estimation method allows us to distinguish between the two effects: "the endogenous social effect," wherein an individual's behavior is directly influenced by the behavior of those in his/her social group, and what Manski (1993) called "the correlated effect," wherein individuals in the same social group tend to behave similarly because of common unobserved factors. As will be explained later, distinguishing between these effects is important to predict the impact of an intervention.

Our results show that the influence of social norms on energy saving behavior (i.e., the endogenous social effect) is small or insignificant, while estimates from simple reduced-form methods are found to be large and highly significant as in previous survey-based studies. This suggests that evidence in those studies may mainly reflect the correlated effect, not the endogenous social effect.

The rest of the paper proceeds as follows. Section 2 reviews related works on the relationship between social norms and pro-environmental behavior. Section 3 explains the survey from which we construct the variables for this study and then provides the summary statistics of those variables. Section 4 outlines our econometric framework; we first describe our structural model and then discuss the method for estimating structural parameters of the model. Section 5 presents the estimation results, and the final section concludes.

2. Literature Review

As "social norms" have more than one meaning, social psychologists argued that differentiating between *descriptive social norms* and *injunctive social norms* is important when examining normative social influences (e.g., Cialdini et al., 1990). Descriptive norms refer to what is commonly done for a given situation (i.e., norms of *is*) and, in contrast, injunctive norms specify what is approved or disapproved of (i.e., norms of *ought*). In this study, we focus on descriptive social norms, for which we use the term "social norms."

There are several ways in which social norms can influence individuals' pro-environmental behavior. If an individual is socially unaccepted by others when deviating from social norms, he/she may be inclined to conform to social norms (Gockeritz et al., 2010). In addition, an individual may use social norms as a guide for his/her own action, especially when uncertain about the cost and environmental effects of that action (e.g., Ek and Soderholm, 2008; Gockeritz et al., 2010; Hage et al., 2009; Nyborg et. al., 2006). Overall, social norms are expected to positively influence individuals' pro-environmental behavior.

This idea has been examined by a number of cross-sectional survey studies in the following manner. First, the social group with whom an individual may interact is defined. It is usually households in the respondent's municipality, the respondent's neighbors or the respondent's friends. Second, social norms within the social group are measured from a response to a survey item. When energy-saving behavior is examined, for example, the question typically asks "(h)ow often do you think your neighbors try to conserve energy? (1 = never, 2 = sometimes, 3 = frequently, or 4 = almost always)" (e.g., Gockeritz et al., 2010). Alternatively, the respondent is asked to assess the statement, "I believe that many other households in my municipality try to reduce their use of electricity (1 = disagree completely, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, or 5 = agree completely)" (e.g., Hage et al., 2009). Finally, as mentioned earlier, a regression is run where the dependent variable is the individual's energy saving action/intention while regressors are the social norm variable as well as a set of control variables.

Previous studies of this type have repeatedly found that an individual's pro-environmental behavior is similar to that of others in his/her social group. For example, Nolan et al. (2008) found that among Californians, social norms are positively associated with energy conservation behavior, although respondents do not think of social norms as an important factor in their conservation decisions. Hage et al. (2009) provided evidence that recycling efforts of Swedish households are positively associated with their perception about how often others in their municipalities recycle. Similar evidence was obtained by Oskamp et al. (1991) and Barr (2007), and further by Corral-Verdugo et al. (2002) and Dahlstrand and Biel (1997) in the context of water conserving behavior and environment-friendly purchasing behavior, respectively.

It should be noted, however, that these studies do not control for simultaneity, common unobserved characteristics and nonrandom group formation. As a result, it is not clear exactly what findings in these studies imply. That is, a positive association between social norms and pro-environmental behavior may emerge from the endogenous social effect, the correlated effect, or from both. Distinguishing between these effects is important because they imply different predictions for the impact of public policy (Manski, 2000; Moffit, 2001). Specifically, endogenous social effects imply that the effect of an intervention on the initial individual spills over to members in his/her social group. Suppose, for example, that by participating in an information program where one learns the seriousness of global warming, an individual becomes environmentally conscious and then starts an energy-saving practice. In the presence of an endogenous social effect, this will, in turn, motivate members in his/her social group to start the same practice. The effect of such a program will, therefore, be even larger than one may think. In contrast, spillover will not occur with correlated effects; the program may influence participants in the program but not others.

3. Survey Design, Variable Definition and Data Set

3.1. Survey Design

In this study, we use data from a Japanese household survey on energy-saving behavior. In a collaborative project with Japanese Ministry of the Environment, Sophia University and Dokkyo University conducted the survey in Soka City, a typical suburb of Tokyo (approximately 25 kilometers away from Tokyo). The population of the city is approximately 240,000 with a population density of 8.9 thousand persons per square kilometer. Although the population is not large, the density is high in comparison to the average in Japan (approximately 0.3 thousand persons per square kilometer). As Soka City is not necessarily a representative city in Japan, our results should not be interpreted as indicating the general tendency of people in Japan.

The survey was implemented in the following procedure. Twelve hundred households were randomly selected from all households in Soka City. Data collectors visited the households from January 7 to February 7, 2011 and provided a questionnaire to a member of each household with an explanation that they would receive a book coupon worth 500 yen by participating in the survey. At a later date, the data collectors revisited the households to collect the questionnaires. Because we used a door-to-door survey method, the response rate is high (59.5 percent), corresponding to replies from 714 households.

A variety of aspects related to energy-saving behavior were inquired about in the survey. In particular, it asked the respondents the extent to which they implement simple energy-saving practices regarding air-conditioners, gas heaters, oil heaters, water heaters and some other electric devices that are recommended by the Energy Conservation Center, Japan (ECCJ, 2010).

Among those energy-saving practices, we examine two practices regarding air-conditioners: setting the air-conditioner temperature at (1) 28 degree Celsius (or higher) in summer and (2) 20 degree Celsius (or lower) in winter. Our focus on these practices is motivated by several factors. First, these practices are relevant to most of the respondents, as almost all households own air-conditioners that typically require setting a target temperature. Second, the 28 degree Celsius setting in summer is one of the most well-known energy-saving practices to the respondents, as it was heavily promoted through mass media such as TV, internet and newspapers in a Japanese government's campaign, the so-called "Cool-biz campaign." [1] The 20 degree Celsius setting in winter is also a well-known practice, though not promoted by the government as much as the 28 degree Celsius setting in summer.

For our analysis, we remove the respondents with incomplete answers from the original sample. As a result, the sample size becomes 529 (313) for setting the air-conditioner temperature at 28 (20) degree Celsius or higher (lower) in summer (winter)

3.2. Variables Used for Analysis and Their Summary Statistics

In this subsection, we first describe variables used for our analysis and then present their summary statistics. The choice variables we examine are based on the following survey items: "(D)o you set the air-conditioner temperature at 28 Celsius degree or higher in summer?" and "(D)o you set the air-conditioner temperature at 20 Celsius degree or lower in winter?" For each of the questions, the respondents were asked to choose from "regularly," "sometimes" or "not at all." We create two indicator variables, each of which takes one if the respondent chose "regularly" for the corresponding practice. Although it is possible to extract more information from the data by using ordered information without combining the "sometimes" and "not at all" categories, we refrain from adopting an ordered choice framework for a computational reason. As will be detailed in the next section, we use a game theoretic approach in our econometric model to determine which combinations of choices are possible equilibria. If we model ordered choices instead of binary choices, the strategy space will become very large and as a result, estimation will be computationally expensive, if not impossible.

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[1] The objective of this campaign is to reduce GHG emissions from households and office buildings and thereby help achieve the Kyoto Target for Japan. It was motivated by the fact that emissions from these sectors kept increasing, while those from transportation and industrial sectors were stable or declining.

Social norms among a group of friends are particularly considered in this study. Regarding the social norm for the practice in summer, we use the following survey item: "how many of your five closest friends regularly set the air-conditioner temperature at 28 Celsius degree or higher in summer?" The share of closest friends who the respondent thinks regularly do so is used as a variable representing the social norm in his/her social group. In an analogous manner, we also create a social norm variable for the 20 degree Celsius setting in winter.

As the survey does not provide information about neighbors or how the respondents think of neighbors' energy-saving practices, we do not address the influence of social norms among neighbors that may also be relevant to energy conservation behavior (e.g., Alcott, 2011; Hage et al., 2009; Göckeritz et al., 2010; Nolan et al., 2008) and pro-environmental behavior in general (Corral-Verdugo et al., 2002; Dahlstrand and Biel, 1997). Notwithstanding, our results will suggest whether previous studies overestimated the influence of social norms among neighbors. This is because the estimation issues we are facing are inherent in estimating social interaction effects.

In addition to social norms, socio-demographic and household factors may also influence the respondents' energy-saving practices. Our models therefore include age, a dummy for being male, a dummy for a bachelor's degree or higher, a dummy for being concerned about environmental issues, a dummy for low income (annual income less than 2 million yen), a dummy for high income (annual income more than 10 million yen), the number of household members, a dummy for ownership of the house and the number of rooms in the house. The models further include two variables that represent the temperatures at which the respondents feel comfortable in summer and in winter.

Table 1 presents the summary statistics of variables used in this study. We find that 36.9% (31.0%) of the respondents regularly set the air-conditioner temperature at 28 (20) degree Celsius or higher (lower) in summer (winter). According to the respondents, 1.289 (1.288) friends out of 5, on average, are regularly engaged in the practice in summer (winter). These figures suggest that despite the Cool-biz campaign by the Japanese government, a majority of individuals are not regularly engaged in these practices, leaving much room for energy conservation in the household sector.

Table 2 exhibits the relationship between the probability of implementing the practice in summer and the number of one's closest friends who do so. The probability seems to be increasing in the strength of the social norm. When none of the friends is engaged in the practice, the probability is 0.297; when three are engaged in the practice, the probability becomes 0.576; it increases up to 0.684 when all of five friends are engaged in the practice. As presented in Table 3, a similar pattern is observed for the practice in winter.

To further describe the relationship, we estimate a naive probit model where the dependent variable is an indicator variable for the practice in summer (winter) and an explanatory variable is the share of friends who are engaged in the practice in summer (winter). Column 1 in Tables 4 and 5 present the estimation results for summer and winter, respectively. For each of the practices, the coefficient on the share is found to be positive and significant at the 1% level. Even after controlling for various factors, we find that for each of the practices, the coefficient remains positive and significant at the 1% level (Columns 2 in Tables 4 and 5). Overall, these results suggest that energy-saving practices are positively and significantly correlated with social norms, consistent with those in previous-survey based studies. It is, however, unclear whether this positive correlation is due to the endogenous social effects or correlated effects since the reduced-form coefficient on the social norm variable may be a result of the endogenous social effects, the correlated effects or both (Manski, 1993).

4. The Model and Estimation

The econometric model is based on the model of binary choice with endogenous social effects and correlated effects (Brock and Durlauf 2001; Krauth 2006). In order to allow for observed correlations across energy saving behaviors of friends, the model incorporates three primary elements: simultaneity, nonrandom group selection, and common random shocks. As our model heavily relies on Krauth's model, see Krauth (2006) for further details.

4.1. Preferences and Choices

Economic agents are individuals, each of whom belongs to a particular peer group. g denotes groups, and i denotes individuals within each group. Each peer group is composed of n_g individuals. No groups are overlapped. The size of group g, n_g, is finite and exogenously given.

Each individual makes a decision whether to implement an energy saving practice, $y_{gi} \in \{0,1\}$. The individual's utility depends on his or her own choice of energy saving practice, choices of other group members in his/her group, and his/her own exogenous characteristics. Specifically, the utility function $u_{gi}(y_{gi}; \mathbf{y}_g, \mathbf{x}_{gi})$ is such that:

$$u_{gi}(1;\mathbf{y}_g, \mathbf{x}_{gi}) - u_{gi}(0;\mathbf{y}_g, \mathbf{x}_{gi}) = \boldsymbol{\beta}\mathbf{x}_{gi} + \gamma \bar{y}_{gi} + \varepsilon_{gi},$$

where $\mathbf{x}_{gi}$ is a vector of constant and exogenous characteristics which are observable in the data, $\mathbf{y}_g$ is a vector of choices made by the members of the group, ε_{gi} captures exogenous characteristics that are not observed in the data, and $\bar{y}_{gi}$ is the average choice made by the other group members:

$$\bar{y}_{gi} \equiv \frac{1}{(n_g - 1)} \sum_{j \neq i} y_{gj}.$$

We assume that each individual can observe the number of other group members for whom y_{gj} = 1, $j \neq i$ (as well as his/her own choice y_{gi}).

On the one hand, the parameter $\gamma \geq 0$ is the endogenous social effects; if $\gamma > 0$, an individual's incentive to choose to implement the energy saving practice is increasing in the fraction of his/her peers that do so. On the other hand, correlation of ε_{gi} across members of a given peer group introduces correlated effects due to nonrandom group selection and common random shocks into the model. For example, in the case of n_g = 3, the joint distribution of characteristics across group members is assumed to take the form as follows:

$$\begin{bmatrix} \boldsymbol{\beta}\mathbf{x}_{g1} \\ \boldsymbol{\beta}\mathbf{x}_{g2} \\ \boldsymbol{\beta}\mathbf{x}_{g3} \\ \varepsilon_{g1} \\ \varepsilon_{g2} \\ \varepsilon_{g3} \end{bmatrix} \sim N\left(\begin{bmatrix} \mu \\ \mu \\ \mu \\ 0 \\ 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \sigma^2 & \rho_x\sigma^2 & \rho_x\sigma^2 & 0 & 0 & 0 \\ \rho_x\sigma^2 & \sigma^2 & \rho_x\sigma^2 & 0 & 0 & 0 \\ \rho_x\sigma^2 & \rho_x\sigma^2 & \sigma^2 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & \rho_\varepsilon & \rho_\varepsilon \\ 0 & 0 & 0 & \rho_\varepsilon & 1 & \rho_\varepsilon \\ 0 & 0 & 0 & \rho_\varepsilon & \rho_\varepsilon & 1 \end{bmatrix} \right),$$

where $\rho_x \in \{-1/(n_g - 1), 1\}$ and $\rho_\varepsilon \in \{-1/(n_g - 1), 1\}$. The distribution is symmetric since the ordering of group members is arbitrary, and ε_{gi} is normalized to have mean zero and unit variance. As in the standard probit model, the observable and unobservable characteristics are assumed to be uncorrelated, i.e., cov(ε_{gi}, $\boldsymbol{\beta}\mathbf{x}_{gi}$) = 0. It is also assumed that there is no correlation between one group member's observables and the unobservables of the other group members, i.e., cov(ε_{gi}, $\boldsymbol{\beta}\mathbf{x}_{gj}$) = 0 for $i \neq i$.

4.2. Equilibruim

Individuals' strategies are, for all $i = 1,\ldots,n_g$,

$$y_{gi}(\mathbf{y}_{g-i}, \mathbf{x}_{gi}) = \begin{cases} 1 & \textit{if } \; u_{gi}(1; \mathbf{y}_g, \mathbf{x}_{gi}) - u_{gi}(0; \mathbf{y}_g, \mathbf{x}_{gi}) > 0 \\ 0 & \textit{otherwise.} \end{cases} \quad (1)$$

Let $\mathbf{Y}_g$ be the set of pure strategy Nash equilibria of the normal form game:

$$\mathbf{Y}_g \equiv \left\{ \mathbf{y}_g \in \{0,1\}^{n_g} \text{ such that equation (1) is satisfied} \right\}.$$

If there is no endogenous effect, equilibrium is unique. If there is an endogenous effect, equilibrium is nonunique for a positive probability measure of preference profiles. Hence, estimation requires the imposition of an equilibrium selection rule in order to pin down the unique likelihood function.

An equilibrium selection rule is a function, $sel(\mathbf{y},\mathbf{Y})$, which assigns a probability to each pure strategy Nash equilibrium:

$$sel(\mathbf{y}, \mathbf{Y}) \equiv \Pr(\mathbf{y}_g = \mathbf{y} \mid \mathbf{Y}_g = \mathbf{Y}),$$

where $sel(\mathbf{y},\mathbf{Y}) \geq 0$, $\sum_{\mathbf{y}} sel(\mathbf{y},\mathbf{Y}) = 1$, and $sel(\mathbf{y},\mathbf{Y}) = 0$ if $\mathbf{y} \notin \mathbf{Y}$. Specifically, this study adopts the low-activity equilibrium selection rule as in Krauth (2006). To put it in different words, we assign probability one to the equilibrium with the lowest value of $\sum_{i=1}^{n_g} y_{gi}$ when multiple equilibria exist.

To see the problem of multiplicity and how the imposed equilibrium selection rule works, consider the simplest case where $n_g = 2$ and $\mathbf{x}_{gi} = 1$ (i.e., a group consists of two individuals and the model does not include any exogenous variable). Figure 1 shows values of (ε_{g1}, ε_{g2}) when $\gamma >$ 0, where the constant term is denoted as α. The shaded area of V is the region of multiple equilibria where $\mathbf{Y} = \{(0,0), (1,1)\}$. This makes the likelihood ill-defined; $\Pr(\mathbf{y}_g = (0,0)) + \Pr(\mathbf{y}_g =$

(1,0)) + $\Pr(\mathbf{y}_g = (0,1)) + \Pr(\mathbf{y}_g = (1,1)) > 1$. The low-activity selection rule for this region is $sel((0,0),\mathbf{Y}) = 1$ and $sel((1,1),\mathbf{Y}) = 0$, which pins down a unique likelihood function.

4.3. Identifying Restrictions

The model is nonparametrically identified under plausible restrictions. In particular, the equal correlation restriction in the same spirit of Altonji et al. (2005), who attempt to identify the effect of attending a Catholic school on students' outcomes separately from the effect of unobserved characteristics, is imposed in our empirical study on energy saving practice: $\rho_\varepsilon = \rho_x \equiv \rho$. The equal correlation restriction stems from the following idea. Suppose that the complete vector of each individual's relevant characteristics is randomly divided into observed and unobserved characteristics. The correlations of observables across peer group members are expected to be equal to the correlations of unobservables across the group members.

4.4. Estimation

Due to nonoverlapping peer groups, we can omit the index of an individual i within a group g for observed characteristics: $\mathbf{x}_g = \mathbf{x}_{gi}$. The data set thus consists of N observations: $(\mathbf{x}_g, \mathbf{y}_g)$ for $g = 1,\ldots,N$. Let $\boldsymbol{\theta}_0 \in \Theta$ be the true parameter vector, and let $\boldsymbol{\theta}$ be arbitrary elements of Θ. The simulated maximum likelihood (SML) estimator of $\boldsymbol{\theta}_0$ is defined as

$$\boldsymbol{\theta}^{SML} \equiv \arg\max_{\boldsymbol{\theta}\in\boldsymbol{\Theta}} \sum_{g=1}^{N} \left(\ln\left(\frac{1}{S} \sum_{s=1}^{S} P_g^s(\boldsymbol{\theta}) \right) + \ln \Pr(\mathbf{x}_g ; \boldsymbol{\theta}) \right),$$

where $\left\{P_g^s(\boldsymbol{\theta})\right\}_{s=1}^{S}$ is a sequence of independent random variables such that

$$\frac{1}{S} \sum_{s=1}^{S} P_g^s(\boldsymbol{\theta}) \xrightarrow{p} \Pr(\mathbf{y}_g \mid \mathbf{x}_g ; \boldsymbol{\theta}).$$

Simulation must be used to estimate the likelihood function since the calculation of Pr($\mathbf{y}_g$| $\mathbf{x}_g$; $\boldsymbol{\theta}$) requires the evaluation of a complex multidimensional integral. To do so, we use the Geweke, Hajivassiliou, and Keane (GHK) simulator. As an equilibrium selection rule is imposed, Pr($\mathbf{y}_g$| $\mathbf{x}_g$; $\boldsymbol{\theta}$) can be rewritten as

$$\Pr(\mathbf{y}_g \mid \mathbf{x}_g;\boldsymbol{\theta}) = \sum_{\mathbf{Y}} sel(\mathbf{y}_g, \mathbf{Y}) \Pr(\mathbf{Y}_g = \mathbf{Y} \mid \mathbf{x}_g;\boldsymbol{\theta}).$$

The GHK simulator for observation g is given by

$$P_g^s(\boldsymbol{\theta}) = \sum_{\mathbf{Y}} sel(\mathbf{y}_g, \mathbf{Y}) GHK(\mathbf{Y}, \mathbf{x}_g, \boldsymbol{\theta}, \xi^s),$$

where $\{\xi^s\}_{s=1}^S$ is an independent pseudorandom sequence and

$$\frac{1}{S}\sum_{s=1}^{S} GHK(\mathbf{Y}, \mathbf{x}_g, \boldsymbol{\theta}, \xi^s) \xrightarrow{p} \Pr(\mathbf{Y}_g = \mathbf{Y} \mid \mathbf{x}_g;\boldsymbol{\theta}).$$

5. Estimation Results

5.1. Basic Estimation Results

The third columns in Tables 4 and 5 display SML parameter estimates from the structural model as well as the corresponding average partial effects. The structural model estimates imply that correlated effects (0.264 in summer and 0.208 in winter) exist, and that endogenous social effects (0.185 in summer and 0.556 in winter) are smaller than those by naive probit models presented in the second columns. In fact, similar to the previous survey-based studies, coefficient estimates on the social norm variable from naive probit models are large and statistically significant (0.759 in summer and 0.956 in winter). In contrast, point estimates of endogenous social effects from the structural model are statistically insignificant at the 5% level. In addition, parameter estimates of correlated effects from the structural model are statistically significant.

Hence, the basic estimates from the structural models imply that close friends are less influential to individuals' decisions on energy-saving behavior than previously thought.

To see the extent of the influence of close friends on individuals' energy-saving behavior, let us consider a representative individual. A representative individual is such that his/her probability of implementing the practices under question is equal to the average (36.86% for air-conditioning temperature setting in summer and 30.99% in winter), and that he/she has no close friends implementing the practices. Table 6 indicates how much this individual's probability of implementing the practices increases if f (= 1,…,5) close friends begin the practices. For instance, if one of his/her friends starts participating in the practices, that is, $f = 1$, the structural model predicts an increase in probability of implementing the practices by 1.406 percentage points, from 36.86% to 38.27%, for the air-conditioning temperature setting in summer, and by 4.022 percentage points, from 30.99% to 35.01%, in winter. The magnitude implied from the structural model is only around one fourth of the increase suggested by the naive model in the case of the summer temperature setting. The naive probit model suggests an increase in the probability by 5.850 percentage point, from 36.86% to 42.71%. In the case of the winter temperature setting, discrepancy of the magnitude between the structural model and the naive model shrinks, but the increase from the structural model is about half of the increase implied by the naive model.

Regarding individuals' characteristics, our results indicate that older people are less likely to implement the practices; as age increases by one, the probability of implementing the practices for summer and winter will decline by 0.002 and 0.003, respectively. Individuals with higher comfortable temperature in summer and those with lower comfortable temperature in winter are more likely to implement the practices. Specifically, one degree increase (decrease) in comfortable temperature is associated with a six (five) percentage increase in the probability of implementing the practice in summer (winter).

We also found that individuals who live with less household members are more likely to implement the practices, possibly because it is easier for everyone to agree with a temperature setting if the number of household members is smaller. The estimated coefficients on income dummies are not statistically significant, as in previous empirical results (e.g., Hage et al., 2009).

We further found that individuals who are interested in environmental issues are more likely to be engaged in the practices. One might be concerned about the endogeneity of this variable, due to which coefficient estimates on the other variables suffer from bias. To check whether this is the case, we estimate models where the variable of interest in environmental issues is excluded. As shown in the fourth columns in Tables 4 and 5, similar results hold in the models, suggesting that our main results are not driven by the endogeneity of interest in environmental issues.

5.2. Bounds on Endogenous Social Effects

The above results are based on estimation under the equal correlation restriction in observables and unobservables. Endogenous social effects turn out to be smaller than those in the previous survey-based studies once we take into account correlated effects as pointed out by Manski (1993). Therefore, we may consider an alternative restriction on correlated effects, which are no larger than the estimates under the equal correlation restriction. In particular, if we impose an alternative interval restriction such that the correlation in unobservables is no more than the estimated correlation in observables, and no less than half of the estimated correlation in observables: $\rho_\varepsilon \in [0.132, 0.264]$ in the case of the air conditioning temperature setting in summer, and $\rho_\varepsilon \in [0.104, 0.208]$ in the case of winter, we can place bounds on endogenous social effects of γ. Figure 2 displays the bounds on endogenous social effects in the case of the temperature setting in summer, which is [0.181, 0.548], and relationship between estimated endogenous social effects and correlation restrictions in unobservables when the equal correlation restriction is relaxed. Figure 3 corresponds to the bounds in the case of the temperature setting in winter, which is [0.571, 0.863]. The values within the bounds on endogenous social effects are smaller than the naive probit estimates (0.759 in summer and 0.956 in winter) respectively, even if we restrict that correlated effects are no larger than the estimated correlation under the equal correlation restriction. In fact, in Figure 2, if the correlation in unobservables is at least around one fourth of the estimated correlation under the equal correlation restriction (that is, $\rho_\varepsilon \geq 0.065$), endogenous social effects turn out to be smaller than the naive probit estimate.

Similar to the basic results, the discrepancy of the magnitude of endogenous social effects between the structural model and the naive model is smaller in winter than in summer. In the case of summer, endogenous social effects are statistically significant at the 5% level, if the correlation in unobservables is not larger than 0.25. Note that a pointwise asymptotic 95 percent confidence interval for the correlation under the equal correlation restriction is $\rho \in [0.103, 0.425]$. Thus, when the correlated effects are in the range from 0.103 to 0.25, they are within the confidence interval under the equal correlation restriction, and the endogenous effects are statistically significant and smaller than those suggested by the naive model. As for the winter setting, endogenous social effects are statistically significant if the correlation in unobervables is not larger than 0.3. Therefore, the same applies if the correlated effects are in the range from 0.036 to 0.3. Since the upper bound of 0.3 is larger than the basic estimate of 0.208 in winter, the difference from the naive model is smaller in winter than in summer.

6. Conclusion

In this study, we used data from a Japanese household survey and examined the influence of social norms on energy-saving practice, in particular, social norms among close friends. Unlike previous survey-based studies, this study adopted a structural estimation approach and dealt with simultaneity and between-peer correlation in unobserved characteristics that are inherent in the estimation of social interaction effects. We found that the endogenous social effects are insignificant or small, if any. In contrast, a standard reduced-form method provides large and significant estimates of the effects. These results suggest that (1) standard methods often used in previous survey-based studies may severely overestimate the influence of social norms and (2) large and significant coefficients on social norm variables in reduced-form studies seem to mainly reflect correlated effects, not endogenous social effects.

It should be mentioned that some studies in the literature do not rely on cross-sectional surveys. Instead, they use randomized natural field experiments in which the methodological issues, i.e., simultaneity and correlation in unobserved characteristics, are adequately controlled for. Those studies found that social norms play an important role in shaping individuals' pro-environmental behavior. For example, Goldstein et al. (2008) conducted several field experiments and found that hotel guests who were informed that "the majority of guests in this room reuse their towels" are more likely to reuse their own towels than those who were simply informed about environmental impacts of washing guest towels daily. Using data from field experiments run by a company named Opower, Allcot (2011) found that the electricity use of residential utility customers who were informed of their neighbors' electricity use was decreased by 2% on average.

We are not against these findings. Indeed, despite our evidence, we do not claim that social norms do not matter to pro-environmental behavior. Rather, what we attempted to do in this study is to demonstrate the importance of controlling for simultaneity, common unobserved characteristics and nonrandom group formation when cross-sectional survey data is used for analysis; if these issues are not adequately dealt with, one may severely overestimate the influence of social norms on pro-environmental behavior. This point is important, we believe, because not all researchers (including us) have luxury of conducting large scale social experiments and on many occasions must rely on survey data. Even when researchers have enough resources for social experiments, they may first conduct a cross-sectional survey study or use results from other cross-sectional survey studies to determine whether to implement a social experiment as well as what the design of the experiment should be. In such a case, for a social experiment to be successful, results from a cross-sectional survey study should be as informative as possible. Biased results can be misleading and may bring about an unexpected or undesirable outcome from a field experiment.

Table 1. Summary Statistics

Variables	Mean	SD	Min	Max
28 Celsius degree setting in summer	0.369	0.483	0	1
Number of friends who set 28 Celsius degree in summer	1.289	1.367	0	5
Share of friends engaged in the practice for summer	0.258	0.273	0	1
*20 Celsius degree setting in winter**	0.310	0.463	0	1
*Number of friends who set 20 Celsius degree in winter**	1.288	1.410	0	5
*Share of friends engaged in the practice for winter**	0.258	0.282	0	1
Age	54.65	13.85	19	84
Male	0.316	0.465	0	1
Marital	0.879	0.326	0	1
Bachelor's degree or higher	0.223	0.417	0	1
Comfortable temperature in summer – 28	-2.134	1.986	-10	2
Comfortable temperature in winter – 20	3.476	2.573	-5	10
Concerned about environmental issues	0.291	0.455	0	1
Income less than 2 million yen	0.081	0.274	0	1
Income more than 10 million yen	0.104	0.306	0	1
Number of household members	3.328	1.350	1	7
Ownership of the *house/apartment*	0.798	0.402	0	1
Number of rooms in the house	4.822	1.502	1	10

Note: The number of the observation is 529 except for variables with * whose sample size is 313.

Table 2. 28 Degree Setting in Summer and the Number of Friends Doing the Practice

How many friends out of 5? (F)	Nobs	Yes (36.9%)	No (63.1%)	Pr(Yes | F)
0	212	63	149	0.297
1	104	30	74	0.288
2	117	49	68	0.419
3	59	34	25	0.576
4	18	6	12	0.333
5	19	13	6	0.684

Table 3. 20 Degree Setting in Winter and the Number of Friends Doing the Practice

How many friends out of 5? (F)	Nobs	Yes (31.0%)	No (69.0%)	Pr(Yes | F)
0	135	31	104	0.230
1	49	10	39	0.204
2	68	24	44	0.353
3	38	22	16	0.579
4	11	4	7	0.364
5	12	6	6	0.500

Table 4. Estimation Results for Setting 28 Celsius Degree in Summer

	(1)		(2)		(3)		(4)	
	Naive Probit		Naive Probit		Structural		Structural	
Variable	Coefficient	APE	Coefficient	APE	Coefficient	APE	Coefficient	APE
Share of friends engaged in the practice (γ)	0.902***	0.330***	0.759***	0.236***	0.185	0.053	0.258	0.079
	(0.205)	(0.071)	(0.223)	(0.067)	(0.273)	(0.065)	(0.307)	(0.067)
ln(*Age*)			-0.834***	-0.259***	-0.676***	-0.195***	-0.588**	-0.180**
			(0.254)	(0.076)	(0.247)	(0.073)	(0.240)	(0.076)
Male			0.193	0.060	0.083	0.024	0.105	0.033
			(0.134)	(0.042)	(0.126)	(0.041)	(0.124)	(0.042)
Marital			0.420*	0.123**	0.402*	0.106*	0.410*	0.114**
			(0.230)	(0.062)	(0.222)	(0.057)	(0.217)	(0.057)
Bachelor's degree or higher			0.078	0.024	0.128	0.038	0.250*	0.080*
			(0.150)	(0.047)	(0.144)	(0.046)	(0.137)	(0.048)
Comfortable temperature in summer – 28			0.189***	0.059***	0.190***	0.055***	0.179***	0.055***
			(0.033)	(0.010)	(0.025)	(0.010)	(0.025)	(0.011)
Concerned about environmental issues			0.802***	0.270***	0.776***	0.250***		
			(0.132)	(0.044)	(0.128)	(0.044)		
Income less than 2 million yen			-0.115	-0.035	-0.060	-0.017	0.005	0.001
			(0.254)	(0.077)	(0.240)	(0.074)	(0.234)	(0.076)
Income more than 10 million yen			-0.046	-0.014	-0.037	-0.011	-0.099	-0.030
			(0.202)	(0.062)	(0.205)	(0.059)	(0.191)	(0.060)
Number of household members			-0.199***	-0.062***	-0.164***	-0.047***	-0.155***	-0.048***
			(0.058)	(0.017)	(0.057)	(0.017)	(0.052)	(0.017)
Ownership of the house/apartment			0.315*	0.095*	0.328*	0.089*	0.374	0.107**
			(0.184)	(0.053)	(0.173)	(0.049)	(0.169)	(0.049)
Number of rooms in the house			-0.061	-0.019	-0.068	-0.020	-0.074	-0.023
			(0.051)	(0.016)	(0.046)	(0.016)	(0.046)	(0.016)
Between-peer correlation in unobservables (ρ)					0.264***		0.234**	
					(0.082)		(0.098)	
Log-likelihood	-338.37		-289.45		-1120.99		-1153.55	

Note: The sample size is 529. APE represents average partial effect. ***, **, and * represent the statistical significance at the 1, 5, and 10 percent levels, respectively. Standard errors are in parentheses. A constant term is included in each model, though not reported here.

Table 5. Estimation Results for Setting 20 Celsius Degree in Winter

	(1)		(2)		(3)		(4)	
	Naive Probit		Naive Probit		Structural		Structural	
Variable	Coefficient	APE	Coefficient	APE	Coefficient	APE	Coefficient	APE
Share of friends engaged in the practice (γ)	1.010***	0.341***	0.956***	0.262***	0.556*	0.147*	0.432	0.120
	(0.262)	(0.071)	(0.290)	(0.076)	(0.321)	(0.077)	(0.331)	(0.080)
ln(*Age*)			-0.944***	-0.259***	-0.876**	-0.231**	-0.793**	-0.221**
			(0.361)	(0.096)	(0.378)	(0.094)	(0.353)	(0.096)
Male			0.188	0.052	0.081	0.022	0.065	0.018
			(0.184)	(0.052)	(0.185)	(0.050)	(0.180)	(0.052)
Marital			-0.187	-0.053	-0.184	-0.050	-0.134	-0.038
			(0.299)	(0.086)	(0.325)	(0.085)	(0.324)	(0.084)
Bachelor's degree or higher			-0.300	-0.079	-0.236	-0.060	-0.067	-0.018
			(0.209)	(0.052)	(0.211)	(0.052)	(0.190)	(0.055)
Comfortable temperature in winter – 20			-0.200***	-0.055***	-0.200***	-0.053***	-0.192***	-0.053***
			(0.035)	(0.008)	(0.036)	(0.008)	(0.034)	(0.008)
Concerned about environmental issues			0.716***	0.211***	0.693***	0.198***		
			(0.178)	(0.053)	(0.179)	(0.053)		
Income less than 2 million yen			-0.593*	-0.144**	-0.464	-0.109	-0.326	-0.084
			(0.252)	(0.073)	(0.356)	(0.073)	(0.348)	(0.077)
Income more than 10 million yen			-0.476*	-0.121**	-0.423	-0.103*	-0.477*	-0.119**
			(0.270)	(0.062)	(0.285)	(0.060)	(0.263)	(0.060)
Number of household members			-0.283***	-0.078***	-0.267***	-0.070***	-0.270***	-0.075***
			(0.081)	(0.021)	(0.086)	(0.021)	(0.081)	(0.021)
Ownership of the house/apartment			0.244	0.065	0.282	0.071	0.366	0.095
			(0.272)	(0.069)	(0.278)	(0.066)	(0.268)	(0.064)
Number of rooms in the house			0.064	0.018	0.053	0.014	0.034	0.010
			(0.068)	(0.018)	(0.077)	(0.018)	(0.070)	(0.019)
Between-peer correlation in unobservables (ρ)					0.208**		0.242**	
					(0.088)		(0.099)	
Log-likelihood	-186.27		-153.02		-639.03		-650.05	

Note: The sample size is 313. APE represents average partial effect. ***, **, and * represent the statistical significance at the 1, 5, and 10 percent levels, respectively. Standard errors are in parentheses. A constant term is included in each model, though not reported here.

Table 6. Percent Change in Doing the Practice if Friends Come to be Engaged in the Practice

	Summer		Winter	
Number of friends	Naive Probit	Structural	Naive Probit	Structural
1	5.850***	1.406	7.027***	4.022*
	(1.739)	(1.726)	(2.222)	(2.187)
2	11.866***	2.827	14.475***	8.220*
	(3.536)	(3.488)	(4.625)	(4.536)
3	23.846***	5.709	29.587***	16.954*
	(6.820)	(7.094)	(8.982)	(9.407)
4	39.781***	10.102	49.010***	30.107*
	(9.507)	(12.597)	(11.434)	(15.842)
5	54.034***	16.009	63.597***	45.631**
	(7.989)	(19.802)	(7.050)	(19.896)

Note: This tables presents by how much a representative individual's probability of doing the energy-saving practice increases when f (= 1,…,5) friends come to be engaged in the practice. ***, **, and * represent the statistical significance at the 1, 5, and 10 percent levels, respectively. Standard errors are in parentheses.

Figure 1. Multiple Equilibria

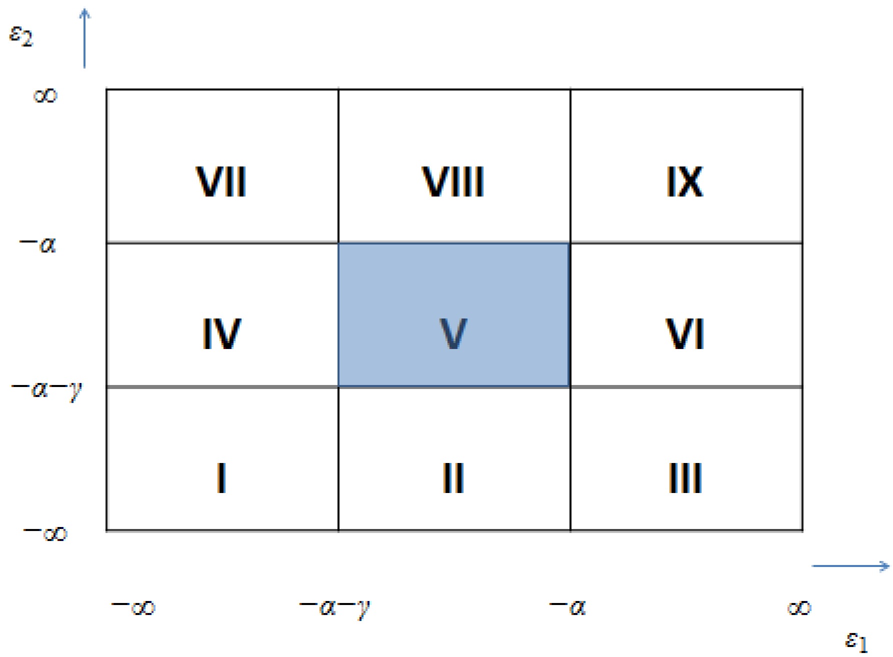
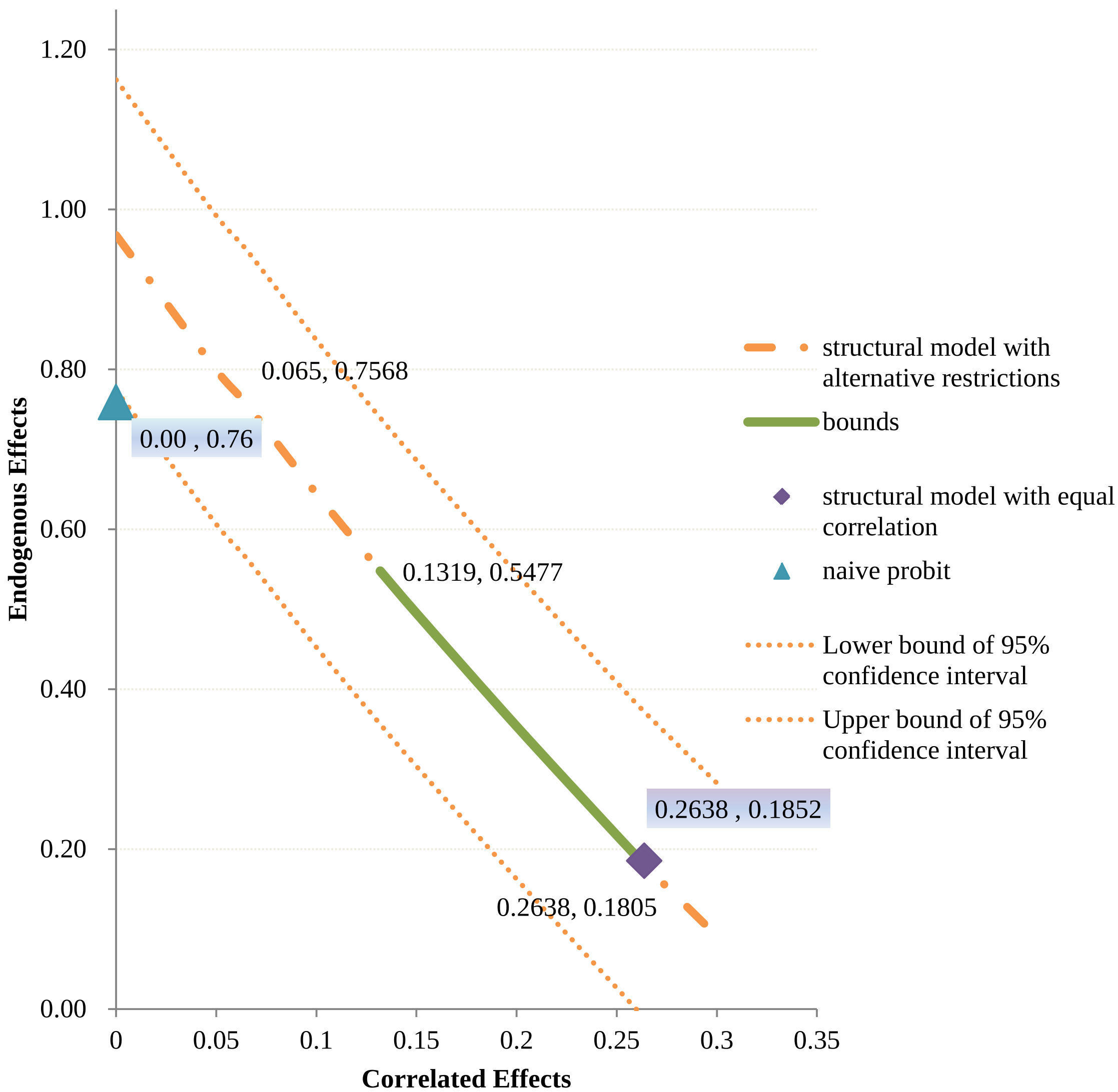
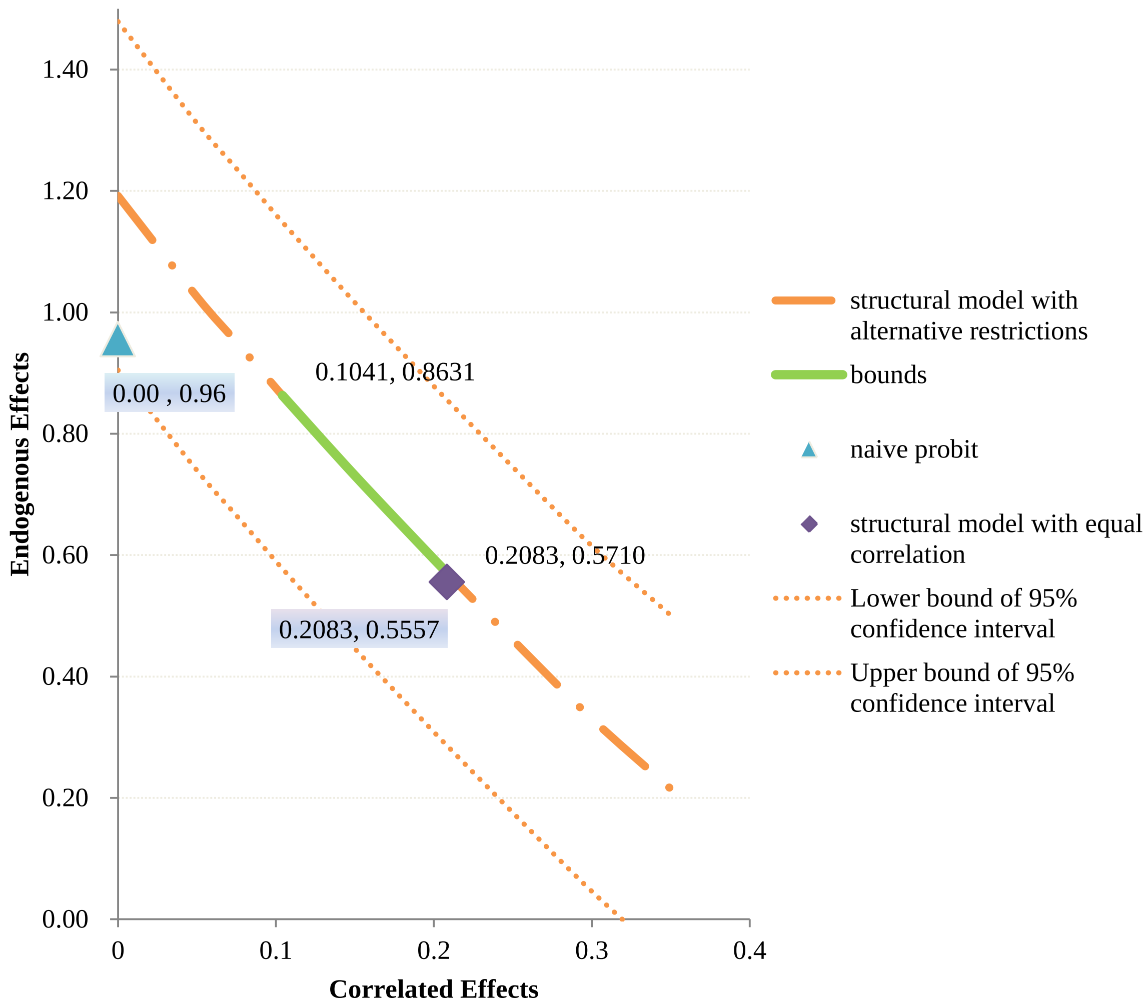


Figure 2. Alternative Restrictions on Correlation in Unobservables, Summer



Note: The blue point represents the point estimate from the naive probit model, while the purple one corresponds to the point estimate from the structural model with the equal correlation restriction. Relaxing the equal correlation restriction, each point on the dotted orange line 'structural model with alternative restrictions' represents the relationship between endogenous effects and correlated effects when the structural model is estimated given a fixed value of correlated effects. The line 'bounds' represent the relationship from the structural model with an alternative interval restriction on correlated effects such that the correlation in unobservables is no more than the estimated correlation in observables under the equal correlation restriction and no less than half of the estimated correlation in observables.

Figure 3. Alternative Restrictions on Correlation in Unobservables, Winter



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