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Abstract

People worldwide aim to reduce the adverse impacts from carbon emissions by adopting clean energy sources. While the literature identifies potential policies, such as carbon taxes, to address this issue, few studies have investigated how these policies can be concretely designed to facilitate cleaner-energy transition. We pose a question of how a carbon tax can be an effective instrument at transitioning to clean energy and hypothesize that providing a set of crucial information with respect to the tax persuades people to support it. We experimentally examine the determinants influencing public support for the introduction of a carbon tax via a vignette experiment with 1500 Japanese subjects. The vignette policy dimensions include "who pays the tax," "how the tax gets paid," "where the revenue gets used" and "how much the burden becomes," each of which is introduced as a treatment with the baseline of "no information" provision. The results indicate that public support comparatively increases when the entities specified to pay are producers, when the tax revenue is used towards renewable energies and when the burden is sufficiently low. Overall, we demonstrate that a carbon tax can be an effective policy instrument for cleaner-energy transition, while garnering public support and ample revenue. To this end, it is necessary to inform people that the carbon-tax policy design targets producers and renewable energy along with a per-capita burden between 500 JPY to 3000 JPY a month.

Key Words: carbon tax; clean energy; policy design; vignette experiment

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Nomenclature

ETS Emission trading system

JPY Japanese yen

OLS Ordinary least square

SVO Social value orientation

US United States

1 Introduction

With the passage of time, the impacts of climate change through an increase in carbon emissions have become apparent (Hughes, 2000, Loucks, 2021). As economies still heavily rely on carbon-producing industries in order to expand, the need for clean-energy sources also increases (Kamat, 2007, Wang et al., 2011, Doğan et al., 2021, Morales Sandoval et al., 2023, Kou et al., 2022). Suitable clean energies are those from renewable sources, including sun, wind and water. These are considered the most practical and sustainable options, because their source is constantly renewed without generating carbon emissions (United Nations, 2023). However, measures to direct societies toward supporting the cleaner-energy transition are known to be complex and difficult, especially with the additional pressure to meet the targets outlined in the Paris Agreement (UNFCCC, 2015, Castrejon-Campos et al., 2020, Motlaghzadeh et al., 2023). Historically, economic and technical benefits have been the primary drivers for many of the energy transitions (Yergin, 2020). This raises the issue of how the general public and societies evaluate both environmental problems and the importance of policies to reduce carbon emissions, as high evaluation ensures policy continuation and consistency (Henderson and Anupama, 2021, Norris et al., 2023). Therefore, we seek to address the possible carbon tax policy design that shall be implemented to not only facilitate cleaner-energy transition but also garner enough public support.

Ample studies have examined public support for policies that promote clean energy in industries and the associated innovations since the 1970s (Asplund, 2012, Hamilton, 2013, Singh, 2021). Some literature, such as Popp (2010), GEA (2012), Daim et al. (2015), Weitemeyer et al. (2015) and Pleßmann and Blechinger (2017), reports that governments should implement policy designs that increase public support for renewable energy and also include a higher percentage of it in the national energy systems. However, this can only be achieved with governments being accountable and efficient. Kaldellis et al. (2012) document that Greece has sought to disseminate renewable energy with this strategy. Although there was high acceptability, further information was requested by general public regarding renewable energy and its usefulness. Stokes and Warshaw (2017) suggest that people are inclined to support the implementation of renewable energy with the information provision on public health and job creation. Having said this, Bergek et al. (2013), Sen and Ganguly (2017) and Pérez et al. (2019) argue that it requires significant investment costs and time, irrespective of the mentioned benefits for renewable energy. Even though there are other instruments, such as renewable portfolio standard and feed-in tariff, to promote clean energy, most of these policies do not gain enough public support, facing a lack of energy diversification, unstable energy supply or a crowd-out effect for R&D investments (Nolden, 2013, Abolhosseini and Heshmati, 2014, Nordensvärd and Urban, 2015, Yu et al., 2016, Hitaj and Löschel, 2019, Newell et al., 2019, Bersalli et al., 2020, Agana, 2021). One exception is a subsidy policy that has proven to be effective in encouraging the adoption of clean energy, and it does so with public support (Ouyang and Lin, 2014, Jingchao et al., 2019). However, it is often financially unstable and unsustainable due to the heavy burden on governmental budgets (Granado et al., 2010, Tietenberg and Lewis, 2011, Goodsteing and Polasky, 2020). These examples demonstrate the challenges in implementing policies that garner public support and achieve the widespread deployment of clean energy (Mey et al., 2016, De Rosa and Castro, 2020).

Further research endeavors aim to analyze the adoption of carbon pricing and its impact on general public as a means to promote the transition toward clean-energy sources by charging emitters on their carbon emissions (Maryniak et al., 2019, Gao et al., 2020, Gokhale, 2021). Metcalf (2009), Aldy and Stavins (2012) and Baranzini and Carattini (2014) argue that the policy instrument is not only necessary due to being market-based but also straightforward to have an effective price incentive in comparison to other policies. This incentive fosters engagements, investments and transitions among individuals and various entities for clean-energy usage (Maibach et al., 2013, Carattini et al., 2018, IEA, 2020b, Thomas et al., 2022). Within carbon-pricing policy instruments, there are mainly two approaches: a carbon tax and an emission trading system (ETS). The former is directly relevant and influential to the general public, in comparison to the latter, and the tax revenue that is generated can not only be utilized for the transition toward cleaner-energy technologies but also garner public support (Amdur et al., 2014). Both Scrimgeour et al. (2005) and Creedy and Sleeman (2006) discuss how the introduction of a carbon tax can result in welfare changes in New

Zealand, which is among the first countries to adopt an implicit carbon tax (OECD, 2022). Scrimgeour et al. (2005) empirically evaluate effectiveness of a carbon tax, energy tax and petroleum tax in New Zealand economy, finding that a carbon tax has adverse effects on household consumption. Creedy and Sleeman (2006) analyze the data from household surveys, finding that households with low total expenditure tend to spend a high proportion of carbon intensive commodities. They argue that such households are negatively influenced by the carbon tax. Andersson (2019) denotes that carbon pricing in Sweden leads to a decrease in carbon emissions, especially in the transportation sector, whereas such reduction is not mirrored on an aggregate level in British Columbia (Felix, 2022). As a consequence, it is argued that the carbon taxes neither necessarily reduce carbon emissions nor have public support due to consumption changes in households, welfare losses and distributional impacts for cleaner-energy transition (Burstein, 2003, Liang and Wei, 2012, Tietenberg, 2013, Daggash and Mac Dowell, 2019, Bromley-Trujillo and Poe, 2020, Lilliestam et al., 2021, Moz-Christofoletti and Pereda, 2021, Compernolle et al., 2022).

While literature has sought to clarify possibilities of several policies for mitigating the emissions and increasing clean-energy use, little studies have addressed how policies can be concretely designed to facilitate cleaner-energy transition and to gain public support in stable and sustainable manners within a single analytical framework. Given this paucity, we pose a question of how a carbon tax can be effectively designed for not only transitioning to clean energy but also garnering public support. We hypothesize that providing a set of crucial information with respect to the tax persuades people to support it for the transition. Specifically, we conjecture that people support a carbon tax when producers bear the payments and the tax revenues are specified to be used for renewable energy within a reasonable range of the tax burden, irrespective of how the tax gets imposed. To test the hypotheses, we empirically examine the determinants influencing public support for the introduction of a carbon tax via a vignette experiment with 1500 Japanese subjects. The vignette policy dimensions include “who pays the tax,” “how the tax gets paid,” “where the revenue gets used” and “how much the burden becomes,” each of which is introduced as a treatment with the baseline of “no information” provision.

2 CO_2 emissions and pricing in Japan and the rest of the world

Japan's economy has been heavily dependent on its manufacturing and technological industries for development (Gerstel and Goodman, 2020). In 2021, Japan was the biggest exporter of machinery, photo lab equipment, large construction vehicles, hot rolled irons and thermostats which are all carbon intensive products (Simoes and Hidalgo, 2011). This is further proof that crude oil and other fuels have traditionally accounted for most of Japan's imports (Kozui et al., 2002); these nonrenewable resources remain the core of the country's electricity generation and industrial production. As a consequence of the aforementioned features in Japan's economic history and development, CO_2 emissions have not been successfully reduced, as can be seen in figure 1, and they are consistent with minor fluctuations. Moreover, due to the geographical position, Japan is susceptible to the impacts of climate change. For instance, over the last 40 years, the number of typhoons approaching Japan from the Pacific side of the archipelago has risen by 20 % (Fujinami, 2020).

[Figure 1 about here.]

Similar to Japan, other developed and emerging nations including China, South Korea, United States (US) and Germany recognize their reliance on carbon-emitting sources for economic growth (Steinberger et al., 2012). As every nation aspires for economic development, the reliance on carbon intensive resources exacerbates the importance of addressing the adverse effects of CO_2 emissions on the environment and climate (Bowen et al., 2012, Baily and Bosworth, 2014, Wu et al., 2023, Ma et al., 2023). The utilization of carbon-intensive fuels in manufacturing processes has notably contributed to the rise in greenhouse gas levels in the atmosphere, resulting in unpredictable weather patterns (Gudmundsson et al., 2017). Figure 1 illustrates that China and US exhibit high CO_2 emissions due to the combustion of fossil fuels and direct industrial activities. This observation, however, is unsurprising considering that both countries have leading manufacturing industries (Baily and Bosworth, 2014). While Japan exhibits low annual emissions, they still surpass those of Germany and South Korea. Also, it is noteworthy to mention that Germany's emission rates are gradually declining, and the trend can be attributed to its efforts in transitioning to clean-energy sources.

To achieve the goals in the Paris Agreement, each nation created its own policy objectives as a means to ensure climate mitigation and the transition toward clean-energy sources. China, one of the largest carbon emitters, adopted a national emission trading system (ETS) and it was the world's largest carbon market (Ali, 2021). Given the recent implementation, its effectiveness remains to be fully assessed. Currently, the policy predominantly targets the power generation sector where coal-fired power plants contribute to nearly half of China's CO_2 emissions resulting from fossil-fuel combustion, being expected to not only reduce emissions but also facilitate the transition toward clean energy by influencing people's demand for less carbon intensive technologies. In South Korea, its energy sector is characterized by the dominance of fossil fuels, and it is for this reason the country hopes to advance its energy sector. It is seeking to increase the share of renewable electricity by 20 %, while gradually phasing out coal and nuclear sources (IEA, 2020a). After rejoining the Paris Agreement, the first ever National Climate Task Force was created, and one of its aim towards clean-energy transition is to reach 100 % carbon pollution-free electricity by 2035 (White House, 2021). Lastly, Germany has been a leader in the global green economy. The country has had numerous progressive environmental policies to transition to renewable energy with its Renewable Energy Sources Act 2000, reflecting Germany's drastic improvement in the past years (Krewitt and Nitsch, 2003).

With the evidence, we deduce that carbon pricing can be an efficient policy tool to not only reduce CO_2 emissions but also facilitate the transition toward clean energy. ETS and carbon tax share the same objective, but they differ in their approach. The decision to use either or both often depends on how policymakers wish to tackle ambiguity, uncertainty as well as emission reduction within a certain time frame. A carbon tax can be designed and controlled by the central authority to reduce carbon emissions. Then, the tax revenues are generated and used for specific purposes. On the other hand, ETS is decentralized for how emission reductions and technological transitions for clean energy shall be made, often resulting in some forms of uncertainties associated with the trading prices and performances (Bruneau, 2004). Compared to ETS, a carbon tax is established to offer certainty in that consumers and/or producers can be aware of the prices as a form of the specific tax payments in advance. The certainty is claimed to aid the central authority to have direct controls and adjustments over the tax revenues and the carbon-tax policy design regarding "who pays the tax," "how the tax gets paid," "where the revenue gets used" and "how much the burden becomes," potentially garnering public support (Carattini et al., 2017). In other words, a carbon tax is considered to have some potentials to be optimally designed for financial sustainability and stability towards cleaner-energy transition with public support. It is high time to examine an optimal carbon-tax policy design for not only Japan but also some nations, since they have not implemented any full-scale carbon pricing policy despite the urgent need (The Asahi Shimbun company, 2022).

3 Research Design

The primary focus of this paper is to investigate the information criteria that should be considered into a carbon-tax policy design in order to ensure public support. Extensive literature examines the resistance that is often encountered toward the implementation of a carbon tax (Ewald et al., 2022, Sterner et al., 2020, Carattini et al., 2018). These studies elucidate the prevailing narrative that individuals are reluctant to accept the responsibility and express dissatisfaction with the distribution of the costs (Carattini et al., 2019, Levi, 2021). However, the literature mostly concentrates on the resistance itself, and there is a notable gap regarding specific implementation factors. Highlighting the need to further explore this aspect in greater depth serves as impetus for the formulation of our hypotheses, which centers around the specific information that holds the most importance to the general public (Dodman and Mitlin, 2013, Hobman and Ashworth, 2013). With this, we focus on four aspects related to the carbon tax policy design: (i) who pays the tax, (ii) how the tax gets paid, (iii) where the revenue gets used and (iv) how much the burden becomes.

First, the substantial contribution that the energy and industrial sectors have made to carbon emissions requires government interventions to implement a carbon tax to mitigate their effects. Metcalf (2009) suggests that levying the tax on producers, rather than consumers, may be perceived as favorable by the public. This approach not only aligns the responsibility to the entity contributing to carbon emissions, while reducing the burden on consumers, but also motivates producers to depend less on carbon-intensive equipments and to promote cleaner-energy transition. Thus, we evaluate the following hypothesis:

Hypothesis 1 (who pays the tax) *People exposed to the information that producers should pay the carbon tax support the introduction of the carbon tax more than those that receive no information about the entities responsible for the tax payment.*

Second, there are two streams of the carbon tax payment method: paying the carbon tax through energy bills and through income or corporate taxes. Energy bills offer individuals great autonomy over their expenses as they are directly influenced by personal usage. In contrast, income or corporate taxes are predetermined by the government and thus leave consumers and producers with less control. In addition, Carattini et al. (2018) claim that introducing a low carbon tax rate has a minor impact on electricity, which suggests that energy bills may foster public support relatively. Then we evaluate the following hypothesis:

Hypothesis 2 (how the tax gets paid) *People exposed to the information that they will pay the carbon tax through their energy bills support the introduction of the tax more than those that receive no information about the tax payment method.*

Third, several studies emphasize that public acceptability of a carbon tax can be increased by providing the information regarding the tax revenue allocation into policies targeting the mitigation of climate changes (Maestre-Andrés et al., 2021). One important example is the promotion of renewable energy with sustainable and environmentally friendly technologies, which also helps decrease the dependency on carbon intensive technologies. There is widespread public support for renewable energy and low-carbon technologies (Hammerle et al., 2021, von Borgstede et al., 2013, Diamond and Zhou, 2022). Then we evaluate the following hypothesis:

Hypothesis 3 (where the revenue gets used) *People exposed to the information that the carbon tax revenue will be used for promotion of renewable energy support the introduction of the carbon tax more than those that receive no information about the allocation of the tax revenue.*

Fourth, imposing taxes involves setting a price on the cost of carbon. This implies that a carbon tax causes carbon-intensive products and services, particularly relating the transportation industry and electricity sectors, to become expensive. A carbon tax decreases people's disposable incomes, putting them in financial constraint. On the other hand, the introduction could be advantageous in the long run, as it encourages consumers and businesses to transition to clean energy technologies and products (Macaluso et al., 2018). Since people are aware of the importance of mitigating environmental degradation, they are willing to support policies targeting the reduction in the detrimental effects of climate change for current and future generations. Thus, it can be considered that to a certain extent, people are inclined to support the notion of paying a reasonable carbon tax. Then we evaluate the following hypothesis:

Hypothesis 4 (how much the burden becomes) *People exposed to the information that carbon tax burden will not be sufficiently high support the introduction of the carbon tax more than those that receive no information about the individual financial burden.*

We conduct an online vignette survey experiment to evaluate which component of the carbon-tax policy design motivates people to support the introduction of the carbon tax. The vignette experiment examines how respondents' attitudes towards a carbon tax are influenced by the information of the four dimensions: (i) the entities responsible for the tax payment (who pays the tax), (ii) the tax payment method (how the tax gets paid), (iii) the allocation of the tax revenue (where the revenue gets used) and (iv) the individual financial burden (how much the burden becomes). Each dimension comprises a combination of three or four domains, with one domain serving as the baseline of "no information" provision, while the remaining two or three domains represent the treatments.

In the first dimension, there are two treatment domains: consumer and producer. The second dimension includes two treatment domains: payment through energy bill and income tax. In the third dimension, there are three treatment domains: promotion of renewable energy, repayment of public debt and support for vulnerable people. Hypotheses 1 to 3 focus on producer as the taxpayer, energy bill as the tax payment method and promotion of renewable energy as the allocation of the tax revenue, respectively. The remaining domains in each dimension are considered for comparison. The fourth dimension pertains to the monthly financial burden per capita and consists of three treatment domains: 500 JPY, 3000 JPY and 10 000 JPY. Hypothesis 4 focuses on possible effects along with an increase in the burden as compared to no information. The four dimensions yield 144 $(= 3 \times 3 \times 4 \times 4)$ conditions, and five conditions are randomly selected out of the 144 conditions for each respondent. A respondent is asked to answer the question "To what extent do you support the introduction of the carbon tax?" by a five-point Likert-scale measurement ranging from 1 (not at all) to 5 (a great deal) under each of the five conditions, providing five responses. Table 1 summarizes the descriptions of the responses, dimensions and domains.

[Table 1 about here.]

The experiment was conducted from March 2023 to April 2023. The sample was randomly drawn from the online panel of Japanese citizens aged 18 years or older of Cross Marketing Inc. The number of respondents who completed the survey is 1500. The sample consists of individuals from urban and rural areas in Japan, ensuring representation across the regions. Since each respondent provides five responses, we have 7500 observations in total for analyses. In the survey, we also collect data on respondents' characteristics, such as age, gender, area and income. Additionally, we collect the measures for respondents' climate perceptions and social value orientations (SVOs) to examine possible heterogeneity in the effects of the information on their attitudes towards the carbon tax. Table 2 summarizes the descriptions of variables representing respondents' characteristics, climate perceptions and SVOs.

[Table 2 about here.]

To measure respondents' perceptions regarding climate change, we follow the work of Hirose et al. (2021). This study conducts a survey which first asks each respondent to carefully read two stories. One story posits that climate change is primarily caused by anthropogenic or human-induced factors, while the other story suggests that it is primarily a result of natural phenomena. After reading the two stories, each respondent is asked to answer a question: "Which story do you find more convincing than the other, or do you find neither story convincing?" Based on the answer, each respondent is classified into two categories: a respondent who agrees that climate change is anthropogenic is classified to have a "human-induced" perception and a respondent who does not agree is classified to have a "non human-induced" perception (See the row *Perception* in table 2).

Concerning the SVO measure, we conduct a decomposed game developed by Van Lange et al. (1997) to identify respondents' social preferences. The SVO concept originates from a game-theoretical approach, which associates with the outcomes for a pair, oneself and the other person, where the other person is unknown to each respondent. The game is called a triple-dominance decomposed game, because each respondent is asked to choose one from three options. An example of the three options is (i) "you receive 500 and the other person receives 100," (ii) "you receive 500 and the other person receives 500" and (iii) "you receive 560 and the other person receives 300." The first option corresponds to a "competitive" orientation that maximizes the gap of the outcomes between oneself and the other $(500 - 100 = 400)$. The second option is a "prosocial" orientation that maximizes the joint outcome $(500 + 500 = 1000)$. The third option is an "individualistic" orientation that maximizes their own outcome (560) irrespective of the other person's outcome. Each respondent answers nine questions, each of which consists of the three options, and is asked to choose one from the three options in each question. The nine choices are used to identify each respondent's orientation. When at least six out of the nine choices are consistent with one of the orientations, the respondent is classified as that orientation. Otherwise, the respondent is classified as "unidentified." In this study, a respondent is classified to be "prosocial" when she has a prosocial orientation. When the respondent has either the individualistic, competitive or unidentified, she is classified to be "nonprosocial" (See the row *SVO* in table 2).

To encourage respondents to participate in the experiment seriously, we paid them some monetary rewards. Each respondent was informed that approximately 2000 JPY would be paid once she completed the survey experiment including questionnaires for her characteristics and climate perceptions. On top of that, the payoff from the SVO game was given to her. The units in the SVO game represented points, and the more points each respondent gained, the more payoff (real money) she would earn from the game. We randomly matched respondents into pairs after eliciting their choices. Each respondent's payoff from the SVO game were determined by summing the points earned from the 9 questions made for herself and the 9 questions that her partner made for her. By applying an exchange rate of 0.2 JPY per point, we determined the real monetary payment for each respondent in the SVO game (400 JPY $\sim$ 900 JPY on average). Overall, respondents took $45 \sim 60$ minutes and the average payment per respondent was 2400 JPY $\sim$ 2900 JPY for participating in the SVO game and vignette experiment along with the questionnaire.

4 Results

Table 3 demonstrates the distributions of respondents and summary statistics of responses across groups and domains in each vignette dimension.[1] We can confirm that the respondents are well distributed across dimensions and domains per dimension, reflecting the randomization process in our vignette experiment. The summary statistics of responses in table 3 reveal some tendency regarding whether or not each of hypotheses 1 to 4 is supported. Regarding WHO dimension, the average response in Producer is higher than that in any other domain, implying that hypothesis 1 shall be supported. Regarding HOW dimension, the average responses are not different across the domains, suggesting that hypothesis 2 shall not be supported. Regarding WHERE dimension, the average response for renewable energy is the highest, and hypothesis 3 is expected to be supported. Regarding BURDEN dimension, the average response in 500 JPY is high as compared to no information, 3000 JPY and 10 000 JPY, and it suggests some possibility that people support the introduction of a carbon tax when the burden is within a reasonable range.

[1]For balance tests, we employ probit regression analyses to estimate the relationships of the covariates with the likelihood of being in each treatment group. The results confirm the effectiveness of randomization in our experiment.

[Table 3 about here.]

To statistically examine hypotheses 1 to 4, we conduct regression analyses focusing on the effects of information provision about the carbon-tax policy design on respondents' attitudes or responses toward the carbon tax. Table 4 presents the results of the Ordinary Least Square (OLS) estimations.[2] The similar values of the estimated coefficients of the domains between the models with and without respondents characteristics, perceptions and SVOs corroborate that randomization works well in our vignette experiment. Figure 2 presents the coefficient plots with the 95 % confidence intervals. The main results drawn from table 4 and figure 2 are as follows. First, concerning the entity responsible for tax payment, the estimated coefficients of consumers and producers are significantly negative and positive, respectively. Public support towards the introduction of the carbon tax increases (decreases) once respondents are informed that producers (consumers) would be responsible for paying the tax. This result supports hypothesis 1 and coincides with Metcalf (2009) that opting to impose the tax on producers, rather than consumers, results in a favorable perception among the public. Since the industrial sector is responsible for a substantial proportion of CO_2 emissions, people tend to perceive that producers should pay for the carbon tax, emphasizing the importance of targeting this sector in any carbon-tax policy (Network, 2008, Bains et al., 2017). Second, regarding the tax payment method, the estimated coefficients of payment through energy bills and income tax are insignificant, and the result does not support hypothesis 2. In contrast to Carattini et al. (2018), respondents are insensitive towards how the tax should be paid.

[Table 4 about here.]

Third, regarding the allocation of tax revenue, the estimated coefficients of renewable energy and those that are vulnerable show a significant positive effect, while the coefficient of public debt is found to be insignificant. This suggests that public support for the carbon-tax policy design increases when respondents are informed that the tax revenue will be utilized for renewable energy initiatives and for aiding those that are vulnerable. The result is supportive of the favorable effects

[2] The estimation results of the ordered probit models are provided at table 6 in Appendix for robustness check, showing the qualitatively similar results as the OLS estimation.

of renewable energy initiatives and corroborates hypothesis 3. It also aligns with the argument of Maestre-Andrés et al. (2021) that the tax revenue allocation targeting the mitigation of climate change increases public acceptability for the tax. In addition, the analysis shows that the public also supports the allocation of tax revenue to assist those who are vulnerable. These findings are considered consistent with Amdur et al. (2014) in that the allocation of the tax revenue towards public concerns garners greater public support.

[Figure 2 about here.]

Fourth, in terms of the tax burden borne by individuals, the estimated coefficients of 10 000 JPY and 3000 JPY are significantly negative, while the coefficient of 500 JPY is significantly positive. Public support for the carbon tax decreases when information reveals that the individual tax burden exceeds 3000 JPY but increases when it is set at 500 JPY. These results provide evidence in favor of hypothesis 4, which coincides with the findings of Jagers et al. (2019) that the level of tax increase influences public support. Importantly, our analysis suggests that people are likely to support the introduction of the carbon tax if the monthly individual tax burden ranges between 500 JPY and 3000 JPY. In summary, our experimental study indicates that the public is receptive to the carbon tax when they are directed towards producers and the development of renewable energy, coupled with a per-capita monthly burden ranging from 500 JPY to 3000 JPY.

For a better understanding of our main results, we further examine how the effects of information provision about the policy design on respondents' attitudes toward the carbon tax relate to three important features: (i) perception regarding climate changes, (ii) SVO and (iii) age. To do so, we conduct three subsample analyses related to the three features (see table 5 and figure 3), confirming that the results in the subsample analyses are generally consistent with our main ones in table 4. Concerning perception regarding climate changes, we divide the full sample into the two subsamples of respondents who agree that climate change is human-induced and those who do not agree, conducting the OLS estimations for each subsample. Figure 3a shows the results of the subsample analyses related to perception regarding climate change (see "perception" column in table 5 for the regression result). The results show some clear disparity between the two groups of respondents. Informing respondents that producers bear the responsibility of paying the carbon tax, and that the tax revenue is directed towards funding renewable energy initiatives, tends to garner high support for the introduction of the carbon tax from those who acknowledge human-induced climate change, as compared to those who do not. One plausible explanation for this could be that individuals who perceive climate change as human-induced are likely to be aware of its causes, and producers are often regarded as the primary emitters. Therefore, they consider that renewable energy is a vital solution to mitigate climate change, being inclined to endorse the introduction of the carbon tax.

[Table 5 about here.]

Similarly, regarding SVO, we divide the full sample into the two subsamples of prosocial and nonprosocial respondents, performing the OLS estimation for each subsample. Figure 3b presents the results of the subsample analyses related to SVO (see "SVO" column in table 5 for the regression result). The subsample analysis indicates that the coefficient of consumer is statistically negative for the subsample of prosocial respondents, while it is insignificant for the subsample of nonprosocial respondents. Informing respondents that consumers bear the responsibility of paying the carbon tax motivates prosocial individuals to support the introduction of the carbon tax less, but this information does not have the same impact on nonprosocial respondents. A reasonable explanation for this is, since prosocial respondents demonstrate a great concern for others, they support the tax less than nonprosocial respondents, as they may think that a tax is not necessarily good for society. In addition, the coefficient of 500 JPY is statistically positive for the subsample of prosocial respondents, while it is insignificant for the subsample of nonprosocial respondents. The information that the monthly tax burden per capita is 500 JPY encourages prosocials to support the introduction of the carbon tax, but this information does not have the same impact on nonprosocial individuals. As previously mentioned, prosocial respondents demonstrate a great concern on society than nonprosocial respondents, and hence introducing the tax burden at a minimal rate would be acceptable for prosocial respondents.

[Figure 3 about here.]

In regards to respondents' age, we divide the full sample into two subsamples of the young generation (less than or equal to 40) and the old generation (over 40s). Figure 3c shows the results of the subsample analysis (see "Age" column in table 5 for the regression result). The estimated coefficients of energy bill and income tax are statistically negative for the subsample of the young generation, while they are insignificant for the subsample of the old generation. Providing the information that the carbon tax is adopted through energy bill and income tax reduces the attitudes towards the carbon tax for young people, but not for old people. This result appears counterintuitive, given that young people often place the responsibility more than old generations do (Skeirytė et al., 2022). Possible justification may relate to young people's perceptions to the relationships between governments and businesses. Corner et al. (2015) mention that the young generation aligns most of the responsibility of catalyzing a response to climate change on government, yet they exhibit a limited level of trust in governmental actions. Once young people receive the information of the tax payment method, their skepticism towards the government becomes pronounced, so that their stance on the carbon tax is undermined. In addition, the analysis reveals that the absolute values of the negative coefficients on the burden (3000 JPY and 10 000 JPY) for old people are larger than for young people. This aligns with Savin et al. (2020) in that concerns about a high tax burden are often expressed by the elderly, often stemming from their strong conviction that numerous taxes are already in place within this age group.

In this research, we have experimentally examined the determinants influencing public support toward introduction of a full-scale carbon tax in Japan via a vignette experiment. Our findings indicate that public support inadvertently increases when the responsible entity is identified as producers, the tax revenue is allocated for renewable energy and the burden is kept sufficiently low. Peimani (2018) and Palmer (2022) document that developed economies have faced challenges due to government deficits and debts, which have made it difficult for them to sustainably and stably finance public policies for mitigating carbon emission as well as transitioning to clean energy. Provided that a carbon tax directly and certainly affects carbon emissions and the general public as compared to other carbon pricing policies, such as emission trading systems (ETS), it is valuable to confirm an existence of carbon-tax policy designs that aligns with general public preferences and needs. This research identifies such an existence that allows for the carbon-tax structures to be in harmony with the general public for cleaner-energy transition and it possibly ensures financial sustainability and stability through garnering enough tax revenues.

5 Conclusion

We have sought to investigate the effectiveness of a carbon tax for promoting clean energy sources via a vignette experiment. Our hypothesis was that the public support for the carbon tax can be influenced by providing crucial information about the policy dimensions. The dimensions are "who pays the tax," "how the tax gets paid," "where the revenue gets used" and "how much the burden becomes," each of which is assumed to be crucial to the carbon-tax policy design. By comparing a variety of information provision with "no information" in each dimension, we specifically identify what matters to influence public support. Our results indicate that informing respondents of the producers as the responsible entity, the use of the tax revenue for renewable energy and a sufficiently low tax burden per capita increases public support for the carbon tax. They also imply that the general public has a desire to mitigate carbon emissions and to transition to renewable energy, as far as the carbon tax-policy design is persuasive. Overall, we demonstrate a possibility that a carbon tax is designed and implemented with enough public support, contributing to stability and sustainability for cleaner-energy transition as well as for public finance.

We finally acknowledge some limitations and discuss future avenues of research. One limitation we identify through conducting this research is the obstacle to quantify the degree of public support for policies. Although this research uses a Likert-scale measurement as the proxy for individual support to each policy design in a vignette experiment, there may exist a better approach to be able to well approximate it, such as conjoint analyses or some other choice experiments. If we have a nice approach to be able to do so, it shall contribute to scientifically designing some policy that is in harmony with people's preferences for some important agendas, such as social security or an environmental problem, where a conflict of interests exists between a government and general public (Hares et al., 2010, Howell et al., 2016, Ganguly et al., 2018). Another limitation is that our study focuses on Japan, a country with unique cultural and geographical characteristics, and our results may not apply to other nations. Future studies should evaluate and understand the differences and commonalities of the policy designs for garnering public support between Japan and the others. Despite these limitations, our work is still important as it demonstrates an existence "a good carbon-tax policy design," serving as further possibilities for future research and policy implementation.

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6 Appendix

For robustness check, we estimate an ordered probit model, and the marginal probabilities are computed and reported in table 6 for the purpose of comparison with the OLS results in table 4. We confirm that the qualitative results remain the same as the OLS ones.

[Table 6 about here.]

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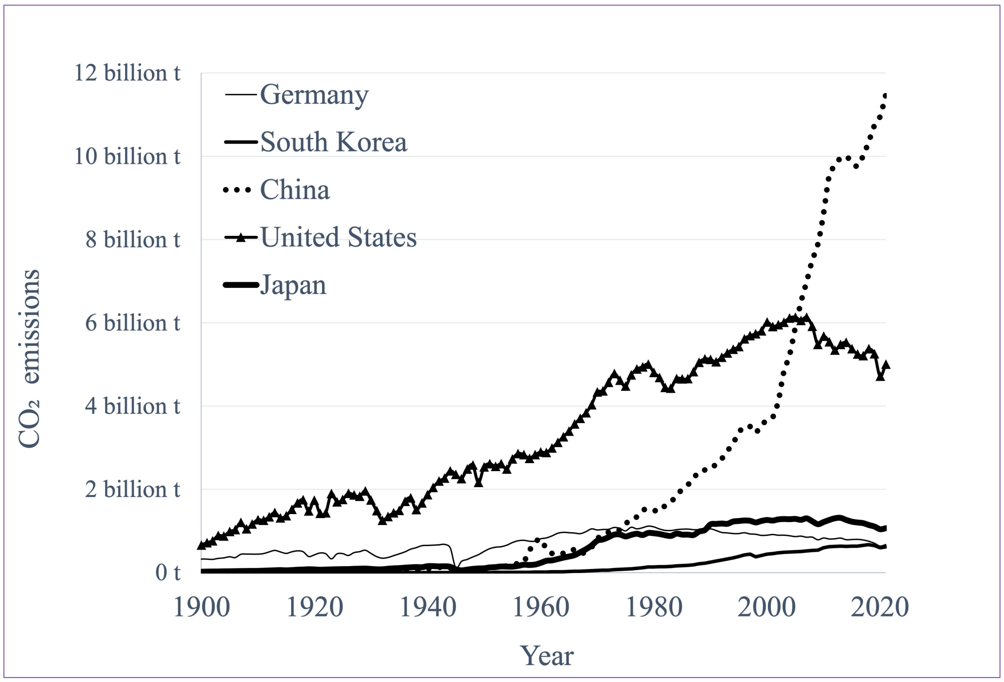


Figure 1: CO_2 emissions by fuel (Ritchie et al., 2020)

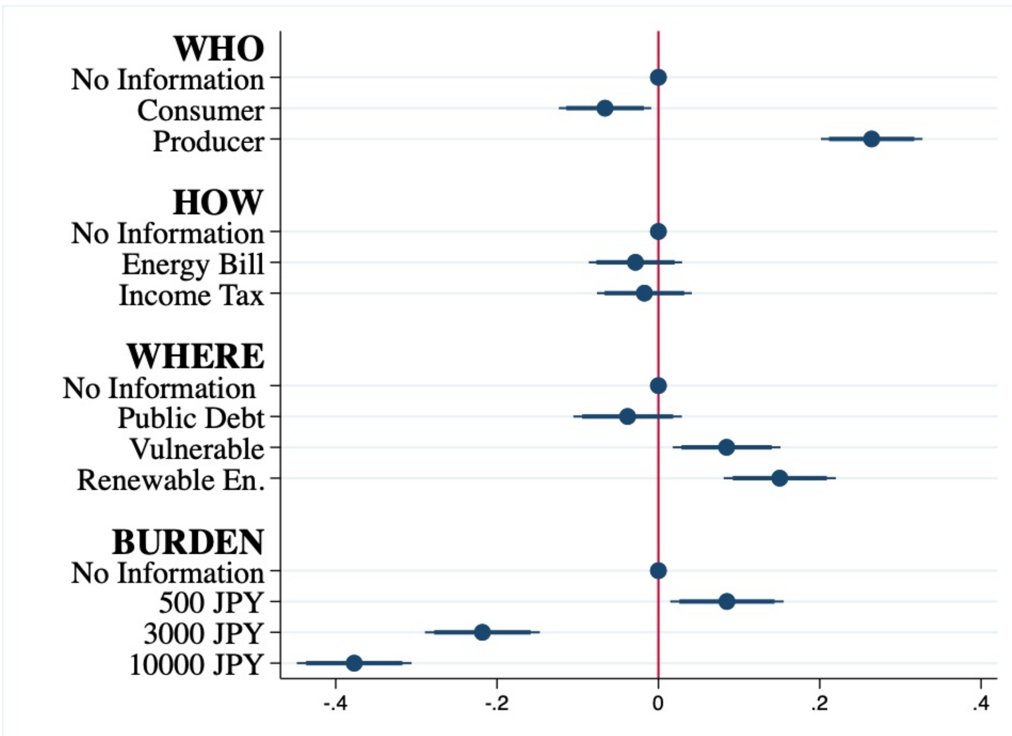
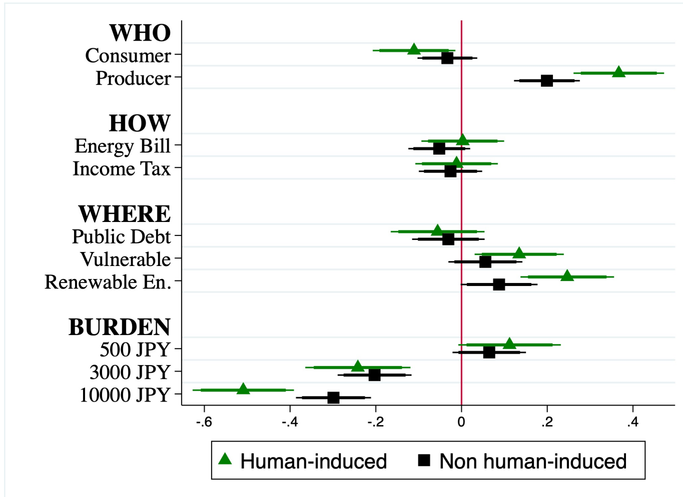


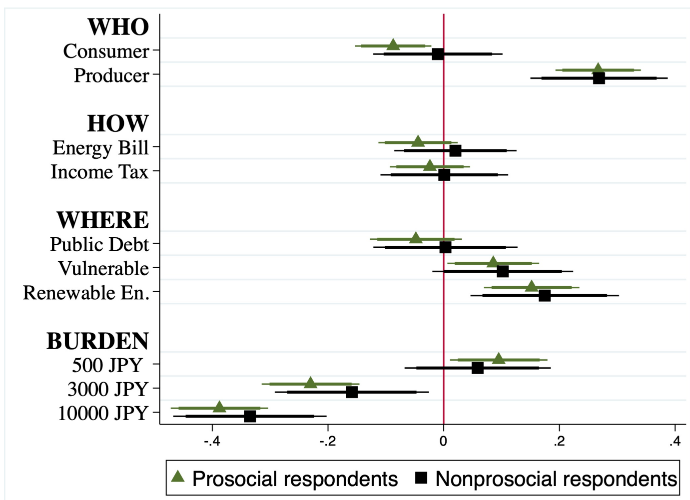
Figure 2: Full sample analysis

Figure 3: Subsample analyses

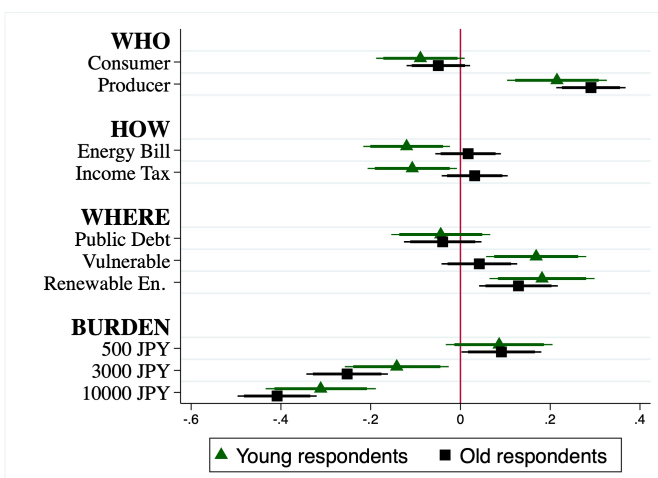
(a) Respondents’ perceptions of climate change



(b) Respondents’ SVO



(c) Respondents’ age



List of Tables

Table 1: Descriptions of the responses, dimensions and domains in a vignette experiment

Variable	Description
Response	Likert-scale measure for support to introduction of a carbon tax ranging from 1 (not at all) to 5 (a lot)
WHO	
Consumer	Dummy variable that takes 1 for consumer and 0 otherwise
Producer	Dummy variable that takes 1 for producer and 0 otherwise
HOW	
Energy Bill	Dummy variable that takes 1 for energy bill and 0 otherwise
Income Tax	Dummy variable that takes 1 for income tax and 0 otherwise
WHERE	
Public Debt	Dummy variable that takes 1 for public debt and 0 otherwise
Vulnerable	Dummy variable that takes 1 for vulnerable people and 0 otherwise
Renewable Energy	Dummy variable that takes 1 for renewable energy and 0 otherwise
BURDEN	
500 JPY	Dummy variable that takes 1 for 500 JPY and 0 otherwise
3000 JPY	Dummy variable that takes 1 for 3000 JPY and 0 otherwise
10 000 JPY	Dummy variable that takes 1 for 10 000 JPY and 0 otherwise

In each dimension of WHO, HOW, WHERE and BURDEN, the baseline is “no information” provision (or absence of information).

Table 2: Variables of respondents' characteristics, climate perceptions and SVOs

Variable	Description
Age	Dummy variable that takes 1 for young (less than or equal to 40) and 0 for old (more than 40)
Gender	Dummy variable that takes 1 for female and 0 for male
Area	Dummy variable that takes 1 for urban areas and 0 for rural areas
Income	Categorical variable that represents low income (less than 4.5 million JPY), mid income (between 4.5 million JPY and 10 million JPY) and high income (more than 10 million JPY) where the base group is low income
Perception	Dummy variable that takes 1 for human-induced and 0 for non human-induced
SVO	Dummy variable that takes 1 for prosocial and 0 for nonprosocial

Table 3: Summary statistics of responses across domains and respondents' characteristics

	Response by a five-point Likert-scale measurement													
	WHO			HOW			WHERE				BURDEN (JPY)			
	No info	*Cons.*	*Prod.*	No info	*En. Bill*	*In. Tax*	No info	*Public Debt*	*Vul.*	*Renew. En.*	No info	500	3000	10 000
Av.	2.17	2.11	2.43	2.25	2.22	2.24	2.19	2.15	2.28	2.34	2.36	2.45	2.15	1.99
SD	1.06	1.04	1.12	1.09	1.08	1.08	1.06	1.08	1.06	1.13	1.07	1.11	1.07	1.02
N	2447	2508	2545	2460	2466	2574	1871	1944	1889	1796	1881	1870	1876	1873
Old														
Av.	2.19	2.14	2.47	2.25	2.26	2.29	2.23	2.19	2.28	2.37	2.41	2.50	2.15	2.00
SD	1.06	1.04	1.13	1.10	1.08	1.09	1.08	1.08	1.05	1.14	1.06	1.14	1.07	1.01
N	1610	1612	1683	1617	1619	1669	1231	1286	1244	1144	1237	1236	1223	1209
Young														
Av.	2.15	2.05	2.35	2.26	2.14	2.15	2.10	2.07	2.29	2.28	2.27	2.36	2.13	1.97
SD	1.05	1.03	1.11	1.08	1.08	1.06	1.02	1.07	1.08	1.10	1.09	1.07	1.06	1.04
N	837	896	862	843	847	905	640	658	645	652	644	634	653	664
Male														
Av.	2.14	2.11	2.42	2.24	2.20	2.23	2.17	2.17	2.25	2.32	2.32	2.42	2.16	2.01
SD	1.09	1.08	1.16	1.12	1.11	1.13	1.10	1.10	1.10	1.17	1.11	1.14	1.12	1.05
N	1481	1502	1517	1495	1452	1553	1126	1166	1122	1086	1115	1122	1136	1127
Female														
Av.	2.22	2.10	2.44	2.27	2.25	2.25	2.21	2.13	2.33	2.36	2.42	2.51	2.13	1.96
SD	1.01	0.98	1.06	1.05	1.03	1.00	1.00	1.03	0.99	1.07	1.00	1.07	0.98	0.97
N	966	1006	1028	965	1014	1021	745	778	767	710	766	748	740	746
Rural														
Av.	2.17	2.12	2.44	2.24	2.24	2.25	2.15	2.19	2.30	2.34	2.38	2.47	2.17	1.95
SD	1.03	1.05	1.10	1.07	1.07	1.08	1.02	1.06	1.06	1.12	1.07	1.12	1.06	0.95
N	1205	1267	1278	1263	1239	1248	911	988	946	905	954	945	930	921
Urban														
Av.	2.18	2.09	2.42	2.26	2.20	2.22	2.22	2.11	2.27	2.33	2.34	2.43	2.12	2.04
SD	1.09	1.02	1.15	1.12	1.09	1.08	1.09	1.09	1.06	1.13	1.07	1.11	1.08	1.08
N	1242	1241	1267	1197	1227	1326	960	956	943	891	927	925	946	952
Low Income														
Av.	2.15	2.04	2.39	2.25	2.16	2.19	2.19	2.11	2.25	2.27	2.31	2.4	2.14	1.94
SD	1.04	1.01	1.15	1.11	1.06	1.07	1.09	1.05	1.07	1.11	1.06	1.12	1.08	1.00
N	845	792	858	840	811	844	606	675	618	596	634	635	609	617
Mid Income														
Av.	2.13	2.10	2.40	2.21	2.20	2.21	2.11	2.12	2.31	2.29	2.35	2.45	2.07	1.96
SD	1.05	1.03	1.11	1.08	1.07	1.07	1.01	1.08	1.06	1.11	1.06	1.11	1.04	1.00
N	1102	1200	1128	1098	1143	1189	847	891	868	824	859	850	852	869
High Income														
Av.	2.30	2.23	2.55	2.36	2.36	2.38	2.33	2.32	2.27	2.55	2.48	2.53	2.31	2.15
SD	1.11	1.08	1.10	1.09	1.12	1.10	1.09	1.09	1.04	1.18	1.10	1.11	1.10	1.07
N	500	516	559	522	512	541	418	378	403	376	388	385	415	387
Non human-induced														
Av.	2.08	2.05	2.29	2.17	2.12	2.14	2.12	2.08	2.18	2.20	2.25	2.32	2.05	1.96
SD	1.02	1.00	1.07	1.05	1.04	1.02	1.03	1.01	1.02	1.08	1.02	1.08	1.00	1.00
N	1459	1504	1542	1481	1498	1526	1104	1178	1127	1096	1151	1103	1125	1126
Human-induced														
Av.	2.31	2.18	2.65	2.38	2.38	2.38	2.29	2.27	2.43	2.55	2.53	2.64	2.29	2.05
SD	1.11	1.08	1.16	1.14	1.12	1.14	1.10	1.16	1.10	1.17	1.12	1.14	1.15	1.05
N	988	1004	1003	979	968	1048	767	766	762	700	730	767	751	747
Nonprosocial														
Av.	2.15	2.16	2.43	2.25	2.25	2.25	2.16	2.18	2.29	2.36	2.36	2.42	2.19	2.01
SD	1.05	1.06	1.10	1.09	1.08	1.06	1.02	1.09	1.09	1.10	1.09	1.07	1.08	1.01
N	677	729	709	706	691	718	519	539	535	522	564	538	503	510
Prosocial														
Av.	2.18	2.08	2.43	2.26	2.21	2.24	2.19	2.14	2.28	2.33	2.36	2.47	2.13	1.99
SD	1.07	1.03	1.13	1.09	1.08	1.08	1.07	1.07	1.05	1.14	1.06	1.13	1.06	1.02
N	1770	1779	1836	1754	1775	1856	1352	1405	1354	1274	1317	1332	1373	1363

Av., SD and N stands for the average, standard deviation and number of observations, respectively.
"*Cons.*," "*Prod.*," "*En. Bill*," "*In. Tax*," "*Vul.*" and "*Renew. En.*" stand for the abbreviations of the domains in table 1, respectively.

Table 4: The OLS estimation results for the support to the introduction of a carbon tax

	Model 1	Model 2
WHO		
Consumer	−0.0657**	−0.0662**
	(0.0293)	(0.0292)
Producer	0.2654***	0.2644***
	(0.0324)	(0.0321)
HOW		
Energy Bill	−0.0300	−0.0284
	(0.0297)	(0.0295)
Income Tax	−0.0165	−0.0174
	(0.0301)	(0.0300)
WHERE		
Public Debt	−0.0458	−0.0381
	(0.0348)	(0.0343)
Vulnerable	0.0823**	0.0846**
	(0.0344)	(0.0340)
Renewable Energy	0.1436***	0.1505***
	(0.0357)	(0.0355)
BURDEN		
500 JPY	0.0895**	0.0850**
	(0.0363)	(0.0358)
3000 JPY	−0.2147***	−0.2182***
	(0.0367)	(0.0363)
10 000 JPY	−0.3764***	−0.3771***
	(0.0366)	(0.0363)
Age (Base group = Old)		
Young		−0.0348
		(0.0485)
Gender (Base group = Male)		
Female		0.0279
		(0.0448)
Area (Base group = Rural)		
Urban		0.0297
		(0.0442)
Income (Base group = Low Income)		
Mid Income		0.0197
		(0.0503)
High Income		0.1664***
		(0.0638)
Perception (Base group = Non human-induced)		
Human-induced		0.2341***
		(0.0462)
SVO (Base group = Nonprosocial)		
Prosocial		−0.0291
		(0.0504)
Observations	7500	7500
R^2	0.0499	0.0656

***, ** and * are significant at the 1 %, 5 % and 10 % levels, respectively
Clustered standard errors by individual respondents are in parentheses.
An intercept is included in each model.

Table 5: The OLS estimation results of the subsamples

	Full	Perception		SVO		Age	
		Human-induced	Non human-induced	Prosocial	Nonprosocial	Young	Old
WHO							
Consumer	−0.0662**	−0.1108**	−0.0331	−0.0873***	−0.0100	−0.0940*	−0.0486
	(0.0292)	(0.0491)	(0.0355)	(0.0336)	(0.0568)	(0.0500)	(0.0357)
Producer	0.264***	0.3669***	0.1992***	0.2670***	0.2685***	0.2108***	0.2922***
	(0.0321)	(0.0538)	(0.0391)	(0.0376)	(0.0604)	(0.0560)	(0.0388)
HOW							
Energy Bill	−0.0284	0.0028	−0.0520	−0.0443	0.0202	−0.1144**	0.0215
	(0.0295)	(0.0492)	(0.0367)	(0.0349)	(0.0538)	(0.0482)	(0.0369)
Income Tax	−0.0174	−0.0116	−0.0258	−0.0238	0.0011	−0.0976*	0.0281
	(0.0300)	(0.0490)	(0.0376)	(0.0353)	(0.0562)	(0.0498)	(0.0375)
WHERE							
Public Debt	−0.0381	−0.0557	−0.0307	−0.0481	0.0030	−0.0236	−0.0305
	(0.0343)	(0.0557)	(0.0431)	(0.0405)	(0.0634)	(0.0556)	(0.0432)
Vulnerable	0.0846**	0.1346**	0.0556	0.0857**	0.1021	0.1805***	0.0450
	(0.0340)	(0.0530)	(0.0440)	(0.0405)	(0.0619)	(0.0560)	(0.0425)
Renewable Energy	0.150***	0.2467***	0.0876*	0.1520***	0.1746***	0.1888***	0.1381***
	(0.0355)	(0.0556)	(0.0457)	(0.0421)	(0.0653)	(0.0591)	(0.0442)
BURDEN							
500 JPY	0.0850**	0.1120*	0.0646	0.0951**	0.0587	0.0744	0.0869*
	(0.0358)	(0.0609)	(0.0437)	(0.0429)	(0.0643)	(0.0596)	(0.0446)
3000 JPY	−0.218***	−0.2419***	−0.2028***	−0.2301***	−0.1588**	−0.1516**	−0.2569***
	(0.0363)	(0.0625)	(0.0439)	(0.0431)	(0.0678)	(0.0585)	(0.0458)
10 000 JPY	−0.377***	−0.5092***	−0.2988***	−0.3876***	−0.3350***	−0.3070***	−0.4142***
	(0.0363)	(0.0602)	(0.0446)	(0.0429)	(0.0674)	(0.0619)	(0.0443)
Observations	7500	2995	4505	5385	2115	2595	4905
R^2	0.066	0.098	0.038	0.078	0.057	0.0657	0.0753

Clustered standard errors by individual respondents are in parentheses.
***, ** and * are significant at the 1 %, 5 % and 10 % levels, respectively
Each model in this table is estimated, including all of the other possible covariates, such as Age, Gender, Area, Income, Perception, SVO and an intercept.

Table 6: Marginal probabilities of domains for the support to the introduction of a carbon tax in the ordered probit model

	Response by a five-point Likert-scale measurement				
	1	2	3	4	5
WHO					
Consumer	0.023**	0.000	−0.011**	−0.011**	−0.002**
	(0.011)	(0.000)	(0.005)	(0.005)	(0.001)
Producer	−0.089***	−0.012***	0.038***	0.050***	0.012***
	(0.011)	(0.002)	(0.004)	(0.006)	(0.002)
HOW					
Energy Bill	0.010	0.001	−0.004	−0.005	−0.001
	(0.010)	(0.001)	(0.005)	(0.005)	(0.001)
Income Tax	0.005	0.000	−0.002	−0.002	−0.001
	(0.010)	(0.001)	(0.005)	(0.005)	(0.001)
WHERE					
Public Debt	0.016	0.000	−0.007	−0.007	−0.002
	(0.012)	(0.000)	(0.006)	(0.006)	(0.001)
Vulnerable	−0.028**	−0.002**	0.013**	0.015**	0.003**
	(0.012)	(0.001)	(0.005)	(0.006)	(0.001)
Renewable Energy	−0.048***	−0.005***	0.021***	0.026***	0.006***
	(0.012)	(0.001)	(0.005)	(0.007)	(0.002)
BURDEN					
500 JPY	−0.025**	−0.006**	0.010**	0.016**	0.005**
	(0.011)	(0.003)	(0.004)	(0.007)	(0.002)
3000 JPY	0.076***	0.008***	−0.034***	−0.040***	−0.009
	(0.012)	(0.002)	(0.005)	(0.006)	(0.012)
10 000 JPY	0.140***	0.004**	−0.064***	−0.066***	-0.014***
	(0.012)	(0.002)	(0.006)	(0.006)	(0.002)
Observations			7500		

Robust standard errors are in parentheses.
*, ** and * represent the significance at the 1 %, 5 % and 10 % levels, respectively.
The marginal probability represents how much the probability of being in one number within a five-point Likert-scale measurement for a response changes when compared to having "no information."