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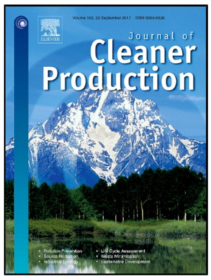

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A new unified approach to evaluate economic acceptance towards main green technologies using the meta-analysis.

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A new unified approach to evaluate economic acceptance towards main green technologies using the meta-analysis.

[1]Abstract

The aim of this paper is to analyze the main determinants of the economic acceptability of four Green Technologies (GTs): alternative fuel vehicles, energy savings in residential buildings, smart meters and renewable electricity, using a meta-analysis on a sample of 35 selected papers, which provided 245 primary data. This approach allows detecting relationships across heterogeneous studies, avoiding the subjectivity of qualitative surveys. We implement a new two-step procedure. First, we compute a measure of the implicit price for a kilogram of CO2 avoided (PCO2), homogenizing the usable information for the GTs considered. Second, we conduct a meta-regression using the computed PCO2 values to estimate the socio-economic determinants' impact. In general, our results show a wide degree of acceptability for GTs which is stronger among European citizens. In particular, it emerges that, on average, the estimated PCO2 is positive for the GTs considered, and additional positive effects exist when respondents are confronted with an explicit reference to quantitative targets in terms of CO2 abatement, a clear proposal for payment timing, and a specific renewable electricity mix. These results indicate that information and transparency are crucial to spur GTs deployment. Therefore, to support GTs' market penetration, public and private institutional stakeholders, have to provide "ad hoc" information to the end users, setting a clear and suitable system of prices to increase the economic value end users place on GTs.

[1] Abbreviations: GT(s) - Green Technology (ies); PCO2 - implicit price for a kilogram of CO2 avoided; AFV - alternative fuel vehicles; BU - energy savings in residential buildings; SM - smart meters; RE - renewable electricity; WTA - willingness to accept; WTP - willingness to pay.

Keywords: CO_2 emissions, green technologies, willingness to pay and accept, unified approach, implicit CO_2 avoided price, meta-analysis.

1. Introduction

In December 2015 in Paris, the 21st Conference of Parties has agreed on the urgent need to substantially decarbonize the global economy and has made another important step toward the goal of defining the continuously evolving concept of a world sustainable development (UN, 2016). In this context, many challenges arise, requiring the balance among economic, environmental and ethical objectives (Gonzalez et al., 2016). Consequently, *"sustainable consumption and production"* (IISD, 1994) is still a key concept to reduce resource use, degradation and pollution, increasing quality of life and welfare gains from economic activities (Lukman et al., 2016). Given that, currently, cities emit 80% of worldwide greenhouse gas emissions and it is predicted that 70% of the world's population will live in urban areas by 2050 (Martos et al., 2016), it is evident cities will deal with important challenges. According to Bloomberg (2014) Report: *"...impact of climate efforts by all cities would be equivalent of cutting world's annual coal use by more than half."*

In detail cities are expected to increase their energy efficiency, to improve energy usage and to reduce emission and pollution. Citizens directly contribute to emissions[2] in a variety of ways, such as electricity use, heating and cooling, air conditioning, refrigeration systems and personal transportation (CSS, 2015). Then, aspects referring to designing sustainable cities are related to the integration of urban transport technologies, building energy consumption and energy behaviors (Martos et al., 2016).

[2] We are aware that on the aggregate, households might contribute to climate change also through the rebound effect. Nevertheless, the rebound effect is difficult to estimate and literature does not provide evidence that energy efficiency gains could be macro-economically reversed by this effect (Gillingham et al., 2015).

According to this scenario, we have selected four green technologies[3] (GTs): alternative fuel vehicles[4] (AFV), energy savings in residential buildings (BU), smart meters (SM) and renewable electricity (RE) mainly focusing on technologies' features that reduce the environmental impact of human activity, not considering social perspectives.

However, despite the importance of the integration among energy and mobility technologies for their successful deployment, researchers and scholars have not jointly investigated acceptability of GTs from an economic point of view.

Following the literature on GTs, it turns out that it is necessary to compare technologies from an economic point of view. We analyze the degree of acceptability of these GTs, taking into account their different degree of potential market penetration. We have handled this issue computing a new unique monetary measure of the different willingness to accept (WTA) and willingness to pay (WTP) of end-users for each GT, through a meta-analysis. The novelty of our approach is to homogenize[5] information about the WTA and WTP for each technology, providing a unique monetary measure to highlight the acceptability of GTs. Such measure, here named PCO2, expresses the implicit price of one kilogram (Kg) of CO2 avoided.

The aim of our paper is twofold. First, we want to compare the different GTs taking into account both technical characteristics and economic dimension. Second, using a meta-analysis,

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[3] Green technologies are typically those technologies that reduce the environmental impact of human activity, agricultural and industrial production (Yanarella et al., 2009). In particular, they can be defined as technologies, which minimize the degradation of the environment, reduce the greenhouse gas emissions, promote healthy and improved environment for all forms of life, and conserve the use of energy and natural resources (Ng et al., 2011).

[4] In this paper, alternative fuel vehicles include electric vehicles and biofuels while renewable electricity do not include electricity generated by hydropower.

[5] As it occurs in the literature on ecological footprint (Rees, 2000), we adopt a unique measure for comparing alternative technologies. Indeed, ecological footprint computations require to calculate human pressure on the planet homogenizing several measures both on the supply and demand side.

we want to shed a new light on the relations between the unified PCO2 measure, and the socio-economic determinants, in order to fully analyze the determinants of the socio-economic acceptability of these GTs.

It should be stressed that, through the meta-analysis, it is possible to suggest directions for future research investigation and foresee their results (Stanley, 2001). Consequently, the meta-analysis implemented in this paper by a two-step procedure -information unification computing PCO2 and meta-regression- can constitute a useful method to the decision support systems for sustainability policies. In particular, as highlighted by Gonzalez et al. (2015), meta-analysis can provide a range of quantitative evidences, conditional on exogenous characteristics that can be of specific interest for the main stakeholders.

Our novel approach allows to fill the gap in the literature by fully comparing and analyzing different GTs belonging to different sectors, starting from the existing literature. Our findings indicate a relatively good stated acceptability of the investigated GTs, although heterogeneity exists. In particular, some negative attitudes emerge only in the case of AFV, while the remaining GTs exhibit positive PCO2 values, meaning that end-users are likely to adopt GTs.

The paper is organized as follows. Section 2 provides the relation between this manuscript and previous research and the data description. Section 3 presents theory and methods. Section 4 presents results and discussion. Section 5 draws conclusions.

2. Related literature and data description

The method of Stanley (2001) is employed performing a systematic literature search to find papers (studies) that investigate the end-users' WTA and/or WTP for four GTs. Indeed, meta-analysis is useful to review a large numbers of studies in the empirical economic literature, given that it requires a systematic approach to summarize research findings (Stanley and Jarrell, 1989).

According to the method used, titles and abstracts in Sciencedirect, Jstor, Ebsco, Scopus and Google Scholar have been queried. Given the topics investigated, most of the useful papers are published after 2000.

The search stretched from June to September 2015. Initially, more than 60 papers, mostly available on the ISI archive, with the exception of two working papers, two chapters of book and three journals not indexed by ISI, have been selected to check whether they contain useful information for computing PCO2[6].

The primary keywords combinations employed in the search are as follows. AFV: WTP, WTA, electric vehicle, alternative fuel vehicle. BU: WTP, WTA, residential buildings. SM: WTP, WTA, smart meters, smart metering. RE: WTP, WTA, renewable electricity, green electricity. According to our literature search, no single paper has jointly focused four GTs and only rarely on more than one GT, confirming the novelty of our approach.

Market failures and barriers hinder the GTs' deployment, given the substantial investments required for improving BU. These latter might not be undertaken by the private households because of the high discount rates, information gaps of householders about the opportunities for saving on fuel bills, transaction costs, riskiness of technologies, and access to credit (Alberini et al., 2013; Clinch and Healy, 2000).

Numerous mechanisms have been introduced to overcome market failures and barriers for GTs' deployment. These include: i) regulation, aimed at improving the performance of the market through the setting of standards (Percival et al., 2013); ii) environmental taxes and subsidies (such as tax credits or deductions) to discourage and encourage certain activities or behavior, respectively

[6] For example, in the RE category, papers have been excluded without data both on current and target share in the electricity generation mix. In some cases, RE share variation in the electricity generation mix is reported but there are not sufficient data for determining the current electricity consumption level. In other cases, the WTP for participating in programs for the development of the new technologies is reported without an explicit reference to the relative quantitative measure of the WTP, thus making it impossible to compute the PCO2.

(Krass et al., 2013); iii) information provision by the government on the benefits of GTs (Owens, 2000); iv) voluntary approaches, established, implemented and complied with on a voluntary basis and generally sponsored by governments (Kotchen, 2013); v) estimation of the economic value that individuals place on green characteristics (Parsons et al., 2014).

This paper pursues the latter, i.e., the estimation of the economic value that individuals place on non-market goods, through the lens of the WTA and WTP of end-users for each GT, interpreted as a proxy for a simulated market behavior. Indeed, there is a growing economic literature that models the green consumer phenomenon, understanding what really motivates green behaviors (Diamantopoulos et al., 2003; Ghosh and Shah, 2015; Zhao et al., 2014). Such understanding is important for policy makers, since the effectiveness of environmental policies depends in large part on how end-users will respond to them. It is also important for businesses because shifts in the demand of green products and services, through the actions of "green" consumers, can affect corporate behavior[7].

AFV represent still a small market share of vehicles in service despite massive policies aimed at reducing gasoline consumption increasingly promote AFV in developed countries. The literature shows that WTP for AFV increases with youth, education and green life style (Ito et al., 2013), even if significant barriers remain in terms of cost and related services for their widespread adoption.

The first step towards the smart grid benefits is the installation of a SM. Scholars have highlighted that end-users value SM and that expected energy saving is the main WTP determinant (Gangale et al., 2013). Significant barriers remain in terms of costs, security and privacy.

Few studies have investigated the WTP for BU even if facades and ventilation are an opportunity to reduce CO2 emissions (Huang et al., 2016). Few results show that income has a positive and

[7] We are aware that actual behavior is usually not observed in the experiments using stated preferences (Carson et al., 2001). Critics highlight that the hypothetical nature of the questions can lead to bias responses and therefore weaken the findings (Mitchell and Carson, 1989). However, accumulated literature has improved the empirical methodology to reduce the gap between actual and hypothetical WTP (Loomis, 2011; 2014).

significant effect on WTP for BU (Banfi et al., 2008). Significant barriers remain in terms of lack of transparent information about their benefits.

Since the 90s (Wiser et al., 1998) a number of studies have estimated WTP for RE (Bigerna and Polinori, 2014). Results show that public interests in RE arise as efficient technologies, but end-users perceive that costs of RE are still high, confirming that the lack of competitively remains the main barrier. According to the aim of our research, we jointly analyze the economic acceptability of these GTs searching for main common economic determinants. Operatively, 35 papers (Table 1) have been selected, which provide 245 primary data (primary information). The publication years range from 2000 to 2015, while the survey data range from 1997 to 2013.

TABLE 1

The most common methods applied in the papers for the GTs concern the experimental nature of the studies, dealing with stated preference methods and deploying random utility theory and contingent valuation. Empirically, binary (Hanemann, 1984) or multinomial logit models (Hanley et al., 1998) estimation methods are applied. The intensity of end-users' efforts to spur the development of such technologies is always analyzed.

3. Theory and methods

The meta-analysis is implemented by a two-step procedure. In the first step, useful information has been homogenized to compute the PCO2 for each GT considered. In the second step, we use homogenized information as dependent variable in a meta-regression, analyzing for each study the WTP/WTA for GTs as a premium for their adoption. In this way, we quantitatively assess end-users' attitudes and perceptions towards GTs.

Meta-analysis is a statistical approach for survey researches widely used in social science because it leads to compare empirical results across studies that may differ in terms of methods, data, time periods and contexts. This approach not only allows to represent findings in a more articulated manner, avoiding the subjectivity of literature surveys[8], but it is also able to detect much more relationships across studies, compared to other approaches (Lipsey and Wilson, 2001). Indeed, the meta-analysis synthetizes and evaluates empirical results across studies to provide comparable estimations of a particular real life phenomenon.

Since middle of 80s, management literature has conducted a large number of studies using meta-analysis (see among others Gooding and Wagner, 1985; Miller and Monge, 1986), mainly focusing on environmental supply chain practices in order to determine and explain the relationship between supply chain and sustainability (Golicic and Smith, 2013). In this paper, we integrate meta-analysis by a secondary analysis[9] (Glass, 1976) in order to homogenize original primary information, thus answering to new questions.

3.1. Theoretical model

The primary information derived from the literature analyzed is used to compute the PCO2, which is a homogeneous measure of the implicit price for avoiding one Kg of CO2 emission[10]. The PCO2 is a measure for assessing end-users' acceptability indirectly through monetary information about

[8] Other methods exist that can be used in alternative way, or integrating the meta-analysis according to the aim of the research. See among others: systematic reviews (Davis et al., 2014), narrative reviews (Möser and Schimdt, 2014). For a survey on the methods for synthesis qualitative and quantitative research please see Barnett-Page and Thomas (2009) and Dixon-Woods et al. (2005).

[9] According to Glass (1976, p. 3), we define secondary analysis: *"the re-analysis of data for the purpose of answering the original research question with better statistical techniques, or answering new questions with old data."* In this paper we have reused data available in the primary studies to compute PCO2.

[10] This measure reflects the preferences of end users and it is a stated value. In the literature, several avoided CO2 prices exist that mainly refer to technological aspects and supply side, such as: the cost of CO2 avoided (Global CCs Institute, 2009), marginal cost of CO2 emission avoided (Enkwist et al., 2007), the average implicit abatement subsidy (Productivity Commission, 2011) and the substitute price of avoiding CO2 emission (Bakhtyar et al., 2014).

the WTA, or WTP, for each GT computed and expressed in EUR cents per Kg of CO2 avoided[11] per year.

First, in the case of AFV, the consumers' PCO2 is computed using the average mileage, fuel efficiency, and the average life of the new vehicles:

$$PCO2 = (C/Y)(V/\mathrm{K}) \quad (1)$$

where *C* is the WTP expressed as the nominal capital expenditure, *Y* is the vehicles life in years, *K* is the average Km per vehicle, *V* is the technical factor which represents the reduction of a Kg of CO2 emission per Km of the AFV with respect to conventional vehicles. For fuel efficiency, we refer to the methodology in Ulman (2016).

Second, in the case of BU, the PCO2 is calculated taking into account the WTP expressed as the capital price *(C)* of dwelling for owners and, alternatively, the rental price *(R)* for rented apartments per month. The percentage premium the respondents are willing to pay for a given retrofitting measure is distinguished in *PRh* for homeowners and *PRr* for rented apartments.

Then, the CO2 emissions *(E)* is obtained by multiplying the average energy consumption per dwelling consumption *(T)*, expressed on tons of oil equivalent (TOE) by the conversion factor of TOE into tons of CO2 (Carbon Trust, 2016):

$$E = T \cdot 2.331 \quad (2)$$

In order to compute the PCO2, the reported energy savings percentage *(S)* is considered for each retrofitting measure and the number of years *(N)* for the amortization of the retrofitting investment.

[11] Operatively, three values of CO2 emissions have been taken into account. They are: $CO2_{ex\text{-}ante}$, $CO2_{ex\text{-}post}$ and $\Delta CO2$, which represent the level of CO2 emissions perceived by the end-users before the introduction of the GTs, the level perceived after the introduction of the GTs and the differences of these two, respectively.

For BU efficiency and retrofitting measures we apply a methodology derived from Michelsen and Madlener (2012), and Banfi et al. (2008). Then, the PCO2 in the case of homeowners is:

$$PCO2 = \left[\left({}^{C}/_{N}\right) \cdot PRh\right]/\left({}^{E}/_{S}\right) \tag{3}$$

while, in the case of rented homes the PCO2 is:

$$PCO2 = (R \cdot 12 \cdot PRr)/\left({}^{E}/_{S}\right) \tag{4}$$

Third, in the case of SM, the measure of PCO2 is constructed considering the consumers' WTP for a one-time capital expenditure *(D)* to install the device in their homes and for a monthly premium on the electricity bill *(M)* for the usage of the device (Pepermans, 2014). All other variables are as defined above. In the case of capital expenditure, the PCO2 is:

$$PCO2 = (D/\mathrm{N})(E \cdot \mathrm{S}) \tag{5}$$

and in the case of monthly premium the PCO2 is:

$$PCO2 = (M \cdot 12)(E \cdot \mathrm{S}) \tag{6}$$

Fourth, in the case of RE, the consumer preferences are used in terms of end-users' WTP for a KWh of RE generated. Then, estimation the CO2 emissions' saving is used to achieve a meaningful measure of PCO2. In the case of RE the PCO2 is (Bigerna and Polinori, 2014):

$$PCO2 = W \cdot \Delta G \cdot H \cdot F \tag{7}$$

where W is the WTP for a percentage variation in the RE share, H is the end-users' electricity average annual consumption, ΔG is the variation in the share of RE and F is the specific CO2 emissions factor for KWh produced monthly. Obviously this latter depends on the specific electricity generation mix for each country in each period.

3.2. Econometric method

According to the meta-analysis literature (Borenstein et al., 2009) we have estimated the meta-regression equation using as dependent variable the logarithm of the PCO2. Formally:

$$\ln\left(PCO2_i\right) = \alpha + \beta_{CO2} MentCO2_i + \sum_{s=1}^{S} \delta_{Sceno_s} Sceno_{s,i} + \sum_{c=1}^{C} \delta_{Cont_c} Cont_{c,i} + \sum_{g=1}^{G} \delta_{Equip_g} Equip_{g,i} + \sum_{m=1}^{M} \delta_{Met_m} Met_{m,i} + \epsilon_i \quad (8)$$

The exogenous variables are constructed to capture several characteristics of the sample, to highlight the existing heterogeneity. A dummy variable *MentCO2* captures the explicit reference to the CO2 reduction proposed to the people surveyed. Indeed, respondents' awareness of climate change implies higher sensitivity to environmental issues and better understanding of their responsibility (Salo et al., 2016). The variable $Sceno_{s,i}$ is a vector of S dummy variables related to the scenario described and to the modality used to submit the elicitation of the WTA/WTP to respondents.

$Cont_{c,i}$ is a vector of C dummy variables related to factual heterogeneity of the sample, indicating: the study location; the study period; the type of respondent and their income. $Equip_{g,i}$ is a vector of G dummy variables referring to the specific features of the equipment related to the four technologies. In addition, such technologies have been classified whether they imply the purchase of services, non-durable and durable equipment. $Met_{m,i}$ is a vector of M dummy variables including methodological features of the survey, such as the elicitation format, the survey type and the sample size. Finally, ε_i is an error term with mean zero and variance σ_i.

The econometric estimation can be performed using different approaches, such as unweighted, weighted least squares and random effects estimator. In particular, weighted ordinary least squares is superior to conventional random effects estimator when the meta-analysis refers to small samples (Stanley and Doucouliagos, 2013) For this reason, the weighted[12] ordinary least squares method is used to estimate Equation 8. It should be stressed that estimates within the same paper tend to cluster (Paldman, 2015; Viscusi, 2015) given that the sample includes multiple PCO2 observations per paper, so that clustered standard errors should be used. Besides, another issue refers to the presence of outliers that may influence the robustness of the meta-regression, affecting the conclusions of the analysis. Then, it is necessary to examine data for potential outliers (Card, 2012).

4. Results and discussion

In this paper, 245 primary information are used to compute PCO2 according to Equations (1-7) and derived from 35 surveyed papers as reported in Table 2.

TABLE 2

These data have been properly used to compute descriptive statistics and then in the meta-regression.

[12] We have calculated the weights as the ratio between the sample size of each primary source and the number of estimated parameters with the respective dataset (Van Houtven et al., 2007; Brons et al., 2008). This allows standard errors to vary across different studies conducted in the same country. Furthermore, this weighting approach can also moderate the effects of publication bias due to sample sizes effect (Stanley, 2005).

4.1. Descriptive analysis

The average values of PCO2, grouped by the four technologies and classified according to Nelson and Kennedy (2009) are reported in Table 3.

TABLE 3

The average PCO2 for the whole sample is a positive value of 6.49 EUR cent/Kg CO2. This means that on average end-users are willing to pay a positive amount to avoid emissions whatever is the type of technology. However, considering different technologies, a negative PCO2 (-6.79 EUR cent/Kg CO2) for AFV results, meaning that end-users are expecting to be subsidized to implement this technology.

The distribution of the values is fairly skewed with large negative values (around -300 EUR cent/Kg CO2). The PCO2 is positive and significantly so, for the other three technologies: 26.2 EUR cent/Kg CO2 for BU, 41.8 for RE and 13.4 for SM. In addition, the minimum value for these last three technologies is positive, meaning that in general end-users are always willing to pay a positive amount. Most of the studies on end-users' WTP for the GTs have been conducted in Europe, followed by Asia, North America and Oceania (Panels A-B, Table 4).

TABLE 4

Most European countries show positive values of PCO2, with significant variability across technologies within a single country (Panel C, Table 4). Anyway, notice that German end-users show a positive PCO2 for all the considered technologies, including AFV. This is an interesting result, given that the other countries have both positive and negative values, meaning that they would require to be compensated for some other technologies, such as AFV.

Indeed, the PCO2 in Germany is higher than the world average and it is about 7.0 EUR cent/Kg CO2. In Switzerland, the PCO2 value is 20.7 EUR cent/Kg CO2, which is quite a high value because it is referring only to the BU and SM technologies. These technologies probably encounter the highest favor of the citizens, because their installation cost is the cheapest and the energy savings results are immediately tangible for their budget. On the contrary, the PCO2 in the US is significantly negative, -10.9 EUR cent/Kg CO2 reflecting the strong attitude requiring a subsidy for AFV.

Considering the time of publication and the four technologies analyzed in the primary information, the first year with data on at least two technologies is 2009 (Panel A, Table 5) and studies for all technologies are available only in 2013 and 2014. According to the pre and post-crisis classification, PCO2 decreases overtime due to the economic crisis (Panel B, Table 5), similar to the findings of Loureiro and Loomis (2010).

TABLE 5

The endogenous variable (first row) and the exogenous variable (other rows) mean values used in the regression are reported in the third and fourth columns of Table 6. In the last two columns, the values of PCO2 conditional on the presence of the exogenous dummy variables are shown in EUR.

TABLE 6

The primary information has been divided depending on whether or not respondents were explicitly requested to consider CO2 reduction in the proposed scenario. In the case of explicit reference to the reduction of CO2, the PCO2 is much higher and always positive, i.e., the explicit reference to CO2 emissions and climate change positively influence the consumers’ attitude.

Papers have been distinguished depending on whether the scenario proposed to the respondents is detailed or generic. The scenario is detailed if respondents are confronted with well-defined GTs technical characteristics (e.g. energy mix, specific building features), while it is generic in the case respondents are confronted with generic defined GTs. However, in this case there are not substantial differences between the two subgroups. A t-test[13] on mean values rejects the hypothesis of different attitudes. One possible justification is that end-users have now acquired a good familiarity with these technologies and they know the relevant features regardless of the accuracy of the survey.

Moreover, the PCO2 differences are classified in terms of the type of equipment of each technology, namely durables (e.g., vehicle, house appliances and other facilities), non-durables (fuels) and services (meters, RE). The PCO2 is higher for services, followed by the non-durable technology and the durable technology.

This is mainly due to two reasons. First, the purchase of a durable technology often includes subsidies if it is environmental friendly. Indeed, in many cases the PCO2 is negative implying the demand for subsidization. Second, the purchase of a durable technology involves a substantial initial payment. In these cases, an increase of the price linked to environmental and efficiency features is perceived as an excessive additional burden, if it has to be borne only on a voluntary basis.

Concerning the methodological aspects, the sample size of the selected papers ranges from 103 to 3029. The analysis of the primary information into quartiles shows that the PCO2 values decrease as the sample size increases. In fact, the larger samples refer to papers dealing with AFV and BU, which are also the technologies recording negative or close to zero values[14]. The papers analyzed show different interviewing methods. In particular, 48.3% of the primary information are collected

[13] For the sake of brevity we have not reported this test that is available upon request.

[14] This relationship has been found also in previous meta-analysis studies (Noonan, 2003). As discussed in the previous section, we have used weighted data and appropriate econometric techniques to handle this aspect.

by Internet, 29.5% by face-to-face, 14.5% by combining two methods (face-to-face and Internet; mail and face-to face) and 7.7% by mail. The PCO2 values are significantly different in the four groups analyzed. The interviews by mail show the highest PCO2 values, while the lowest PCO2 values emerge from interviews that combine the methods. The PCO2 value is particularly low in the case of face-to-face interviews; however, such interviews refer only to AFV and BU.

There are three groups of empirical methods used in the papers: choice experiment or conjoint analysis, double or multiple bound dichotomous and open-ended questions. The highest PCO2 values occur when double or multiple bound dichotomous and open-ended questions are applied. These results confirm the theoretical expectations (Carson et al., 2001) and they are in line with other empirical results in the literature (Barrio and Loureiro, 2010).

In the reviewed papers, the end-users' WTP has been elicited in different ways: i) WTP asked for a specified time period; ii) WTP asked monthly or bimonthly; iii) WTP asked annually; iv) WTP asked for a one-time payment. The PCO2 value, obtained from the WTP, is higher when associated with a clear definition of the time horizon. This result is explained by the greater credibility associated with this type of formulation.

Another important issue refers to the type of respondent (Bigerna and Polinori, 2014). According to the literature, most of the surveys conducted on individuals rather than on households lead to higher WTP (Quiggin, 1998). In this case, most of the papers on WTP for AFV and BU are surveying individuals, implying that PCO2 values obtained on the individual basis are lower than those studies surveying households. Analyzing data for homogeneous subgroups in terms of both methodological and factual variability, differences tend to decrease (Nelson and Kennedy, 2009).

We have graphically inspected our data, to detect possible outliers in the meta-regression results, as shown in the box plots for GTs in Figure 1; in Panel A, we report the full distribution, confirming the existence of a high heterogeneity in the AFV. Inspection suggests that AFV data distribution includes several outliers, and RE and SM have very few outliers. As it is shown in Figure 2, Panel B the small sub-sample BU is quite homogeneous. According to the literature (see among others Dalhuisen et al., 2003), we have excluded[15] around 9% of the primary AFV information, because they could have an influence on the regression analysis. Indeed, given that these extreme values have opposite signs, it would have been difficult to pick up such values by dummy variables. The box plots of the reduced sub-samples are shown in Figure 1, Panel B.

FIGURE 1

FIGURE 2

4.2. The meta-regression

The model has been estimated using the reduced sample according to Equation (8); results[16] are shown in Table 7.

TABLE 7

[15] Using Boxplot (Turkey, 1977) outliers are tagged in graphical way. We have identified a primary information as outlier if it lies outside of the interval [Q1-3(Q3-Q1); Q3+3(Q3-Q1)]. The interquartile range (Q3-Q1) is a robust estimator of variability. We want to stress that any primary study has been excluded in the outliers' removal procedure.

[16] According to an anonymous referee, we have tested the robustness of our model by clustering data in several ways. It is well known that, in meta-analysis, estimates within the same paper tend to cluster. However, we have also clustered by country, category and year of publication, and results are quite robust. R-Cran packages: robustmeta (Fisher et al., 2016), clubSandwich (Pustejovsky, 2016) and metaphor (Viechtbauer, 2016) have been used.

Focusing on the scenario[17] futures, the econometric estimation shows the significance of explicit reference to CO2 reduction equipment. The marginal effect shows that the PCO2 value is higher by 3.8% in the case of an explicit reference to CO2 reductions made in the primary analysis. Also, PCO2 values are higher by 3.15% in the case of not explicit reference to a technology mix. At first sight, this result may appear counterintuitive. However, it can be explained by the wider use of this type of scenario in the contingent evaluation methods with respect to the choice experiment method, which usually asks a much more detailed set of questions about the technology mix. In our sample, the choice experiment is mainly used for AFV[18], where PCO2 is lower compared to the other GTs, as discussed in section 4.1.

Focusing on the way the payment is required (effect of the parameters *WTPdu* and *WTPop*), the implied PCO2 values are lower by about 1.3% when the respondents are confronted with a lump sum choice and a not well defined timing for payment. This may occur because respondents show a lower degree of trust and, therefore, they tend to underestimate the value of the proposed technological scenario.

The effect of the contextual features is significant. Considering geographic location (effect of the parameter *Deu*), the empirical results confirm that studies conducted in Europe significantly contribute to raising the level of PCO2, by about 4.6% (the estimated coefficient is significant at the 1% level) while the contrary occurs, with a higher magnitude, for the studies conducted in North America. There is also a significant difference in the respondents' attitude due to the great economic crisis, as shown by the dummy for the year 2008.

Socio-economic features also play a role in determine PCO2 levels. The *Income* parameter is in line with the economic theory expectations (0.002, significant at 1% level), implying that, on average,

[17] In the contingent valuation and choice experiment studies, it is of fundamental importance that respondents fully understand the features of the scenario proposed, so that the elicitation's process leads to reliable, not distorted, results.

[18] Controlling for interaction of scenario with choice experiment, the parameter scenario becomes positive even if it is not significant; this weakly support our explanation.

income positively affects PCO2. The difference between the PCO2 values for households and individual surveys *(Indiv)* is not statistically significant. As mentioned before, this is a result that is consistent with the literature (Barrio and Luoreiro, 2010).

The effect of the equipment features is not always statistically significant in explaining the sample variances, despite signs are consistent with expectations. The durable technology *(DurgG)* shows a negative and statistically significant sign, while the coefficient associated with the non-durable technology *(NDurG)* is not significant and it has a very low magnitude. This confirms the hypothesis that durable technologies purchase is perceived as an additional burden, implying the need for subsidization.

Also for quite well known technologies such as BU and SM, it is conceivable that respondents could not fully assess the relating value, as highlighted by not significant parameters estimated. This means that an effort is required to deepen the knowledge of GTs.

Finally, we take into account the methodological features. The different interviewing methods do not explain the existing variance. In particular, the parameter *DFtoF* is not significant, although positive as in other meta-analyses. This occurs also for the other variables in the model tested and discarded through the F-test. As confirmed in the meta-analysis literature (Barrio and Loureiro 2010), lower PCO2 values result when using a mix of methods *(Dmixsurv)*. Indeed, this result could confirm that mixed interviewing methods yield more robust and conservative estimates.

Multiple or double bounded elicitation methods (effect of the parameter *Dbd*) lead to higher PCO2 values by 1.3%, as confirmed by the literature. Regarding the sample size, the PCO2 values are usually higher in smaller samples. However, in this paper the effect of *Quantile* is not statistically significant. In any case, it should be emphasized that, over time, papers dealing with stated preferences are refining more and more the methodological aspects and are using larger samples.

4.3. Discussion

The estimated results show that the more are evident the environmental consequence of GTs, in terms of CO2 abetment, the higher is the acceptability and, consequently, the PCO2. This suggests that policymakers and firms have to better explain the positive externalities of GTs proposed. Consumers and citizens are more supportive if the environmental benefits are clearly comprehensible. We argue that knowledge of environmental issues affects the formation of attitudes and beliefs and is directly related to individuals' behaviors, supporting the idea that individuals with a higher knowledge are more likely to pay higher prices in order to benefit from environmental improvements. This is a particularly important issue because it confirms that our empirical findings can be plausibly interpreted as potential predictors of market behavior. In other words, quantitative responses become more reliable as a function of a controllable characteristic of the sample surveyed.

Among socio-economic features, income is the variable with the strongest impact on the consumer's decision to adopt GTs. This result could be interpreted as individuals with higher incomes value to a greater extent the benefits from GTs. Although we are aware that income and environmental issues' knowledge are correlated, this reinforces the previous conclusion, i.e., the possibility to infer simulated market behavior from the stated preference analysis.

Moreover, the type of equipment affects PCO2 that is lower for durable technologies (AFV and BU) with respect to services (SM) and non-durable technologies (RE). The differences in the quantitative measures of PCO2 for different technologies open innovative opportunities for businesses, because it shows that the same level of environmental effect can be priced differently in the market. Thus, these results can provide guidance for marketing strategies related to GTs' deployment.

End-users trust also depends on the understandable of the payment vehicle adopted to support GTs. Well and clearly designed price mechanisms allow increasing the willingness to support GTs; this means that reducing the uncertainty in payment mechanisms could improve GTs acceptability and their market penetration.

In a long run perspective, environmental policy also plays an important role by shaping the environmental attitude and preferences of the society. Controlling for contextual features, it arises that regions in which environmental policy has been earlier implemented show a higher attitude to GTs, thus providing a higher economic support. It is the case of the European countries. It should be stressed that these results are not GT specific, given that we have jointly analyzed four GTs, underlying that a common pathway to spur GTs exist and should be sought involving end-users, policymakers and industrial sector.

Our empirical analysis may be used as a broad frame that facilitates managers and other private and public stakeholders trying to better integrate GTs into consumption and production patterns.

From the managerial standpoint, the results of this study show that, to deploy successfully GTs, manufacturers can assess the economic value individuals place on GTs characteristics as a whole, and accordingly develop suitable pricing strategies. Furthermore, they should provide information about GTs' environmental benefits, in order to increase GTs' knowledge and the economic value end users place on GTs.

In a long run perspective, public stakeholders should promote environmental policy, increasing GTs' end users attitude and preferences toward a greener society. In a short run perspective, public and private stakeholders should cooperate to reach transparency of GTs' technical characteristics and clarity of incentives system, thus increasing the end users degree of trust for such technologies.

5. Conclusions

This paper has investigated, in monetary terms, the main determinants of social acceptability of GTs worldwide, through a meta-analysis. The four GTs analyzed in the paper, i.e., AFV, BU, SM and RE, reflect human high impact activities. A comprehensive review of the relating WTP papers is provided, contributing to construct a comprehensive measure of the implicit price for avoiding one Kg of CO_2 emission. In order to reach this objective, information from about 35 papers have been gathered, recovering 220 primary information for the meta-regression.

The reviewed papers indicate relatively good acceptability of the investigated technologies overall. Results highlight the important conclusion that the PCO2 value is positive on average, meaning that end-users are willing to support GTs to avoid CO2 emissions. However, considering the AFV technology, the empirical results show a negative PCO2 value, implying that end-users expect to be supported in monetary terms to deploy AFV. The remaining technologies show different positive PCO2 values, confirming a good degree of acceptability. The highest value refers to RE, followed by BU and SM. In addition, the explicit reference to the CO2 reduction in the survey positively influences the PCO2 that is much higher and always positive compared to the case where there is not its reference.

Regarding geographical locations, the distribution of papers is mainly in Europe, then Asia, North America and Oceania. At the country level, positive PCO2 values occur in most of the European countries, reflecting the traditional environmental positive attitude of these populations. Notice that Germany shows a virtuous behavior among European countries, showing positive PCO2 values for all the considered technologies. In the North America, the average value for all the technologies is negative, meaning that generally end-users require a compensation for deploying GTs, with particular reference to AFV.

Meta-regression provides useful information to support GTs development. Indeed, results highlight that uninformed respondents are sensitive to accurate description of the new technologies in relation to CO2 abatement. Furthermore, the PCO2 value is positive when respondents are confronted with an explicit timing for paying the premium for GTs deployment. In this case, consumers and citizens' trust increases.

In addition, given that we have jointly estimated determinants of PCO2, this paper highlights that the WTA/WTP for GTs might be considered as strategic information for both private companies and policy makers, for enhancing their business plans and policy instruments geared at CO2 reduction. Our results could help to identify the relevant determinants of PCO2 that can be useful for strategic investment decisions in order to integrate GTs into consumption and production patterns. Indeed, private companies and policy makers can use the degree of GTs acceptability as an argument in their dialogue to decide the target level of incentives. Our findings, thorough the jointly analysis of GTs' PCO2, might help to know when such GTs will be subsidy free over time and how to spur this process. Besides, both private and public stakeholders should pursue transparency of GTs' technical characteristics so that end users' trust can be enhanced.

Further research efforts would help clarify which are the successful conditions for the deployment of environmental policies aimed at improving GTs, also considering social perspectives. There is need to analyze more in depth the issues of reliability of stated preferences when conducting surveys on the WTP for GTs deployment, integrating meta-regression approach with other method of synthesis. There is need to clarify whether substantial differences in primary research findings exist according to a three-step meta-study approach (meta-data, meta-method and meta-theory, Zhao, 1991 and Ritzer, 1991). Also, it is necessary to use primary studies that have been discarded due the absence of complete set of quantitative primary data. In this context, the textual narrative synthesis (Lucas et al., 2007) allows to recover more homogenous groups of information from such primary studies. It will be also useful to include more technologies into the analysis, in line with Internet of Things perspective. Indeed in this perspective every physical object, facility and technology can be linked to the network with the aim of increasing efficiency and minimizing energy consumption and emission. This requires new solutions to accommodate the scalability problem of the GTs deployment toward a new economic paradigm where economic activities and ecology do not clash anymore.

References

Achtnicht, M., 2012. German car buyers' willingness to pay to reduce CO2 emissions. Climatic Change 113, 679–697.

Achtnicht, M., Madlener, R., 2014. Factors influencing German house owners' preferences on energy retrofits. Energy Policy, 68, 254–263.

Alberini, A., Banfi, S., Ramseier, C., 2013. Energy efficiency investments in the home: Swiss homeowners and expectations about future energy prices. Energy J. 34, 49-86.

Axsen, J., Mountain, D.C., Jaccard, M., 2009. Combining stated and revealed choice research to simulate the neighbor effect: The case of hybrid-electric vehicles. Resour. Energy Econ. 31, 221–238.

Bakhtyar, B., Ibrahim, Y., Alghoul, M. A., Aziz, N., Fudholi, A., & Sopian, K., 2014. Estimating the CO2 abatement cost: Substitute price of avoiding CO2 emission (SPAE) by renewable energy's feed in tariff in selected countries. Renew. Sustain. Energy Rev. 35, 205-210.

Banfi, S., Farsi, M., Filippini, M., Jakob, M., 2008. Willingness to pay for energy-saving measures in residential buildings. Energy Econ. 30, 503-516.

Barnett-Page, E., Thomas, J., 2009. Methods for the synthesis of qualitative research: A critical review. BMC Med. Res. Method. 9, 59-70.

Barrio, M., Loureiro, M.L., 2010. A meta-analysis of contingent valuation forest studies. Ecol. Econ. 69, 1023–1030.

Batley, S.L., Colbourne, D., Fleming, P.D., Urwin, O., 2001. Citizen versus consumer: Challenges in the UK green power market. Energy Policy 29, 479–487.

Batley, S.L., Fleming, P.D., Urwin, O., 2000. Willingness to pay for renewable energy: Implications for UK green tariff offerings. Indoor Built. Environ. 9, 157–170.

Bigerna, S., Polinori, P., 2012. Households' willingness to pay for renewable energy sources in Italy: a bidding game approach, in: Uvalic, M., (Ed.), Electricity markets and reforms in Europe. Franco Angeli, Milano, pp. 61–84.

Bigerna, S., Polinori, P., 2013. A bidding game for Italian households' WTP for RES. Atl. Econ. J. 41, 189–190.

Bigerna, S., Polinori, P., 2014. Italian consumers' willingness to pay for renewable energy sources. Renew. Sustain. Energy Rev. 34, 110-121.

Bigerna, S., Polinori, P., 2015. Assessing the determinants of renewable electricity acceptance integrating meta-analysis regression and a local comprehensive survey. Sustain. 7, 11909-11932.

Bloomberg, 2014. Why cities. http://unenvoy.mikebloomberg.com (accessed 28.10.16).

Bočkarjova, M., Rietveld, P., Knockaert, J.S.A., 2013. Adoption of electric vehicle in the Netherlands – A stated choice experiment. Tinbergen Institute Discussion Paper TI2013-100/VIII. http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2306505 (accessed 22.10.16).

Bollino, C.A., 2009. The willingness to pay for renewable energy sources: The case of Italy with socio demographic determinants. Energy J. 30, 81–96.

Borenstein, M., Hedges, L.V., Higgins, J.P.T., Rothstein, H., 2009. Introduction to Meta-Analysis, John Wiley & Sons, Chichester, UK.

Brons, M., Nijkamp, P., Pels, E., Rietveld, P., 2008. A meta-analysis of the price elasticity of gasoline demand: A SUR approach. Energy Econ. 30, 2105–2122.

Carbon Trust, 2016. Conversion factors. https://www.carbontrust.com/conversionfactors (accessed 03.09.16)

Card, N.A., 2012. Applied Meta-analysis for Social Science Research, Guilford Press, New York.

Carson, R.T., Flores, N.E., Meade, N.F., 2001. Contingent valuation: controversies and evidence. Environ. Resour. Econ. 19, 173–210.

Clinch, J.P., Healy, J.D., 2000. Domestic energy efficiency in Ireland: Correcting market failure. Energy Policy 28, 1-8.

CSS-Center for Sustainable Systems, 2015. Carbon footprint. Pub. No. CSS09-05, University of Michigan.

Dagsvik, J.K., Wennemo, T., Wetterwald, D.G., Aaberge, R., 2002. Potential demand for alternative fuel vehicles. Transp. Res. Part B 36, 361–384.

Dalhuisen, J.M., Florax, R.J.G.M., de Groot, H.L.F., Nijkamp, P., 2003. Price and income elasticities of residential water demand: A meta-analysis. Land Econ. 79, 292-303.

Davis, J., Mengersen, K., Bennett, S., Mazerolle, L., 2014. Viewing systematic reviews and meta-analysis in social research through different lenses. SpringerPlus, 511.

Diamantopoulos, A., Schlegelmilch, B.B., Sinkovics, R.R., Bohlen, G.M., 2003. Can socio-demographics still play a role in profiling green consumers? A review of the evidence and an empirical investigation. J. Bus. Res. 56, 465-480.

Dimitropoulos, A., 2014. The influence of environmental concerns on drivers' preferences for electric cars. Tinbergen Institute Discussion Paper No. 2014-128/VIII, Amsterdam.

Dixon-Woods, M., Agarwal, S., Jones, D., Young, B., Sutton, A., 2005. Synthesising qualitative and quantitative evidence: A review of possible methods. J. Health Serv. Res. Policy 10, 45–53.

Enkvist, P.A., Naucler, T., Rosander, J., 2007. A cost curve for green house gas reduction. McKinsey Q.1, 35-45.

Farsi, M., 2010. Risk aversion and willingness to pay for energy efficient systems in rental apartments. Energy Policy 38, 3078–3088.

Fisher, Z., Tipton, E., Hou, Z., 2016. robumeta: Robust variance meta-regression. https://CRAN.R-project.org/package=robumeta (accessed 25.10.16).

Gangale, F., Mengolini, A., Onyeji, I., 2013. Consumer engagement: An insight from smart grid projects in Europe. Energy Policy 60, 621-628.

Gerpott, T.J., Paukert, M., 2013. Determinants of willingness to pay for smart meters: An empirical analysis of household customers in Germany. Energy Policy 61, 483–495.

Ghosh, D., Shah, J., 2015. Supply chain analysis under green sensitive consumer demand and cost sharing contract. Int. J. Prod. Econ. 164, 319-329.

Gillingham, K., Rapson, D., Wagner, G., 2015. The rebound effect and energy efficiency policy. Rev. Environ. Econ. Policy 10, 68-88.

Glass, G.V., 1976. Primary, secondary and meta-analysis. Educ. Res. 5, 3–8.

Global CCS Institute, 2009. Strategic analysis of the global status of carbon capture and storage. Report 5: synthesis report, Global CCS Institute, WorleyParsons, Canberra.

Golicic, S.L., Smith, C.D., 2013. A meta-analysis of environmentally sustainable supply chain management practices and firm performance. J. Supply Chain Manag. 49, 78–95.

Gonzalez, E.D.R.S., Sarkis, J., Dolgui, A., Koh, L., Govindan, K., Jin, M., Zhang, Z., 2016. Low carbon economy and equitable society: Production, supply chain, and operations management perspectives. J. Clean. Prod. 117, 7-9.

Gonzalez, E.D.R.S., Sarkis, J., Huisingh, D., Huatuco, L.H., Maculan, N., Montoya-Torres, J.R., de Almeida, C.M.V.B., 2015. Making real progress toward more sustainable societies using decision support models and tools: Introduction to the special volume. J. Clean. Prod. 105, 1-13.

Gooding, R.Z., Wagner, J.A., 1985. A meta-analytic review of the relationship between size and performance: The productivity and efficiency of organizations and their subunits. Adm. Sci. Quart. 30, 462-481.

Grösche, P., Schröder, C., 2011. Eliciting public support for greening the electricity mix using random parameter techniques. Energy Econ. 33, 363–370.

Hackbarth, A., Madlener, R., 2013. Consumer preferences for alternative fuel vehicles: A discrete choice analysis. Transp. Res. Part D 25, 5–17.

Hanemann, 1984. Welfare evaluations in contingent valuation experiments with discrete responses. Am. J. Agric. Econ. 66, 332-341.

Hanley, N., Wright, R.E., Adamowicz, V., 1998. Using choice experiments to value the environment. Environ. Resour. Econ. 11, 413–428.

Helveston, J.P., Liu, Y.M., Feit, E.M., Fuchs, E., Klampfl, E., Michalek, J.J., 2015. Will subsidies drive electric vehicle adoption? Measuring consumer preferences in the U.S. and China. Transp. Res. Part A: Policy Pract. 73, 96–112.

Hidrue, M.K., Parsons, G.R., Kempton, W., Gardner, M.P., 2011. Willingness to pay for electric vehicles and their attributes. Resour. Energy Econ. 33, 686-705.

Hoen, A., Koetse, M.J., 2014. A choice experiment on alternative fuel vehicle preferences of private car owners in The Netherlands. Transp. Res. Part A 61, 199–215.

Huang, B., Mauerhofer, V., Geng, Y., 2016. Analysis of existing building energy saving policies in Japan and China. J. Clean. Prod. 112, Part 2, 1510-1518.

Ida, T., Murakami, K., Tanaka, M., 2014. A stated preference analysis of smart meters, photovoltaic generation, and electric vehicles in Japan: Implications for penetration and GHG reduction. Energy Res. Soc. Sci. 2, 75–89.

IISD-International Institute for Sustainable Development, 1994. Oslo roundtable on sustainable production and consumption. http://www.iisd.ca/consume/oslo000.html (accessed 03.10.16)

Ito, N., Takeuchi, K., Managi, S., 2013. Willingness-to pay for infrastructure investments for alternative fuel vehicles. Transp. Res. Part D 18, 1–8.

Ivanova, G., 2005. Queensland consumers' willingness to pay for electricity from renewable energy sources. In Proceedings of the Ecological Economics in Action Conference, Massey University, Palmerston North, New Zealand, 11–12 December 2005.

Kaufmann, S., Künzel, S.K., Loock, M., 2013. Customer value of smart metering: Explorative evidence from a choice-based conjoint study in Switzerland. Energy Policy 53, 229–239.

Kesternich, M., 2010. What drives WTP for energy efficiency when moving? Evidence from a Germany-wide household survey. Discussion Paper No. 11004. ZEW. http://ftp.zew.de/pub/zew-docs/dp/dp11004.pdf (accessed 04.10.16).

Kim, J., Park, J., Kim, H., Heo, E., 2012. Assessment of Korean customers' willingness to pay with RPS. Renew. Sustain. Energy Rev. 16, 695–703.

Koetse, MJ, Hoen, A., 2014. Preferences for alternative fuel vehicles of company car drivers. Resour. Energy Econ. 37, 279-301.

Kotchen, M.J., 2013. Voluntary- and information-based approaches to environmental management: A public economics perspective. Rev. Environ. Econ. Policy 7, 276-295.

Krass D., Nedorezov T., Ovchinnikov A., 2013. Environmental taxes and the choice of green technology. Prod. Oper. Manag. 22, 1035–1055.

Kwak, S.-Y., Yoo, S.-H., Kwak, S.-J., 2010. Valuing energy-saving measures in residential buildings: A choice experiment study. Energy Policy 38, 673–677.

Lipsey, M.W.,; Wilson, D.B., 2001. Practical Meta-Analysis (Applied Social Research Methods), Sage Publications, Thousand Oaks, CA.

Loomis, J.B., 2011. What's to know about hypothetical bias in stated preference valuation studies? Journal of Economic Surveys (2011) Vol. 25, No. 2, pp. 363–370

Loomis, J.B., 2014. Strategies for overcoming hypothetical bias in stated preference surveys. Journal of Agricultural and Resource Economics 39(1):34–46, 2014

Loureiro, M.L, Loomis, J.B., 2010. How sensitive are environmental valuations to economic downturns? Evidence fromthe 2009 recession. University of Santiago de Compostela Working Paper. http://www.bioecon-network.org/pages/12th_2010/Loureiro_2.pdf (accessed 10.10.16)

Lukman, R.K., Glavič, P., Carpenter, A., Virtič, P., 2016. Sustainable consumption and production – Research, experience, and development – The Europe we want. J. Clean. Prod. 138, 139-147.

Mabit, S.L., Fosgerau, M., 2011. Demand for alternative-fuel vehicles when registration taxes are high. Transp. Res. Part D 16, 225–231.

Martos, A., Pacheco-Torres, R., Ordóñez, J., Jadraque-Gago, E., 2016. Towards successful environmental performance of sustainable cities: Intervening sectors. A review. Renew. Sustain. Energy Rev. 57, 479-495.

Michelsen, C.C., Madlener, R., 2012. Homeowners' preferences for adopting innovative residential heating systems: A discrete choice analysis for Germany. Energy Econ. 34, 1271–1283.

Miller, K. L., Monge, P. R., 1986. Participation, satisfaction, and productivity: A meta-analytic review. Acad. Manag. J. 29, 727–753.

Mitchell, R. C. and R. T. Carson. 1989. Using Surveys to Value Public Goods: The Contingent Valuation Method. Baltimore: Johns Hopkins University Press forResources for the Future.

Möser, G., Schmidt, P., 2014. Meta-analysis: An alternative to narrative reviews for synthesising social science research? Faculty for Social and Cultural Science, Justus-Liebig University Giessen.

Nelson, J.P., Kennedy, P.E., 2009. The use (and abuse) of meta-analysis in environmental and natural resource economics: An assessment. Environ. Resour. Econ. 42, 345–377.

Ng, F.Y., Yew, F.K., Basiron, Y., Sundram, K., 2011. A renewable future driven with Malaysian palm oil-based green technology. J. Oil Palm Environ. 2, 1–7.

Noonan, D., 2003. Contingent valuation and cultural resources: a meta-analytic review of the literature. J. Cult. Econ. 27, 159–176.

Owens, S., 2000. Engaging the public: Information and deliberation in environmental policy. Environ. Plan. A 32., 1141–1148.

Paldam, M., 2015. Meta-Analysis in a nutshell: Techniques and general findings. Econ.: The Open-Access, Open-Assessment E-J. 9, 1-14.

Parsons, G.R., Hidrue, M.K., Kempton, W., Gardner, M.P., 2014. Willingness to pay for vehicle-to-grid (V2G) electric vehicles and their contract terms. Energy Econ. 42, 313-324.

Pepermans, G., 2014. Valuing smart meters. Energy Econ. 45, 280–294.

Percival, R.V., Schroeder, C.H., Miller, A.S., Leape, J.P., 2013. Environmental Regulation: Law, Science, and Policy. Wolters Kluwer Law & Business, New York.

Potoglou, D., Kanaroglou, P., 2007. Household demand and willingness to pay for clean vehicles. Transp. Res. Part D 12, 264–274.

Productivity Commission, 2011. Carbon Emission Policies in Key Economies, Research Report, Canberra.

Pustejovsky, J., 2016. clubSandwich: cluster-robust (sandwich) variance estimators with small-sample corrections. https://CRAN.R-project.org/package=clubSandwich (accessed 25.10.16).

Quiggin, J., 1998. Individual and household willingness to pay for public goods. Am. J. Agric. Econ. 80, 58–63.

Rees, W.E., 2000. Eco-footprint analysis: Merits and brickbats. Ecol. Econ. 32, 371–374.

Rihar, M., Hrovatin, N., Zoric, J., 2015. Household valuation of smart-home functionalities in Slovenia. Util. Policy 33, 42-53.

Salo, M., Nissinen, A., Lilja, R., Olkanen, E., O'Neill, M., Uotinen, M., 2016. Tailored advice and services to enhance sustainable household consumption in Finland, J. Clean. Prod. 121, 200-207.

Stanley, T.D., 2001. Wheat from chaff: Meta-analysis as quantitative literature review. J. Econ. Perspect. 15, 131-150.

Stanley, T.D., 2005. Beyond publication bias. J. Econ. Surv. 19, 309–345.

Stanley, T.D., Doucouliagos, H., 2013. Better than random: weighted least squares meta-regression analysis. School Working Paper –Economic Series- Deakin University, 2/2013.

Stanley, T.D., Jarrell, S.B., 1989. Meta-regression analysis: A quantitative method of literature surveys. J. Econ. Surv. 3, 161–170.

Turkey, J.W., 1977. Exploratory Data Analysis. Addison-Wesley, Reading, MA.

Ullman, D.F., 2016. A difficult road ahead: Fleet fuel economy, footprint-based CAFE compliance, and manufacturer incentives. Energy Econ. 57, 94–105.

UN-United Nations, 2016. Report of the Conference of the Parties on its twenty-first session, held in Paris from 30 November to 13 December 2015. FCCC/CP/2015/10.

Van Houtven, G., Powers, J., Pattanayak, S.K., 2007. Valuing water quality improvements in the United States using meta-analysis: Is the glass half-full or half-empty for national policy analysis? Resour. Energy Econ. 29, 206–228.

Viechtbauer, W., 2016. metafor: Meta-analysis package for R. https://CRAN.R-project.org/package=metafor (accessed 22.10.16).

Viscusi, W. K., 2015. The role of publication selection bias in estimates of the value of a statistical life. Am. J. Health Econ. 1, 27-52.

Wiser, R., Pickle, S., Goldman, C. 1998. Renewable energy policy and electricity restructuring: A California case study. Energy Policy 26, 465–475.

Yanarella, E.J., Levine, R.S.., Lancaster, R.W., 009. Research and solutions: "Green" vs. sustainability: from semantics to enlightenment. Sustain. J. Rec. 2, 296–302.

Yoo, S.H., Kwak, S.Y., 2009. Willingness to pay for green electricity in Korea: A contingent valuation study. Energy Policy 37, 5408–5416.

Zalejska-Jonsson, A., 2014. Stated WTP and rational WTP: Willingness to pay for green apartments in Sweden. Sustain. Cities Soc. 13, 46–56.

Zhao, H.H., Gao, Q., Wu, Y.P., Wang, Y., Zhu, X.D., 2014.What affects green consumer behavior in China? A case study from Qingdao. J. Clean. Prod. 63, 143-151.

Zoric, J., Hrovatin, N., 2012. Household willingness to pay for green electricity in Slovenia. Energy Policy 47, 180–187.

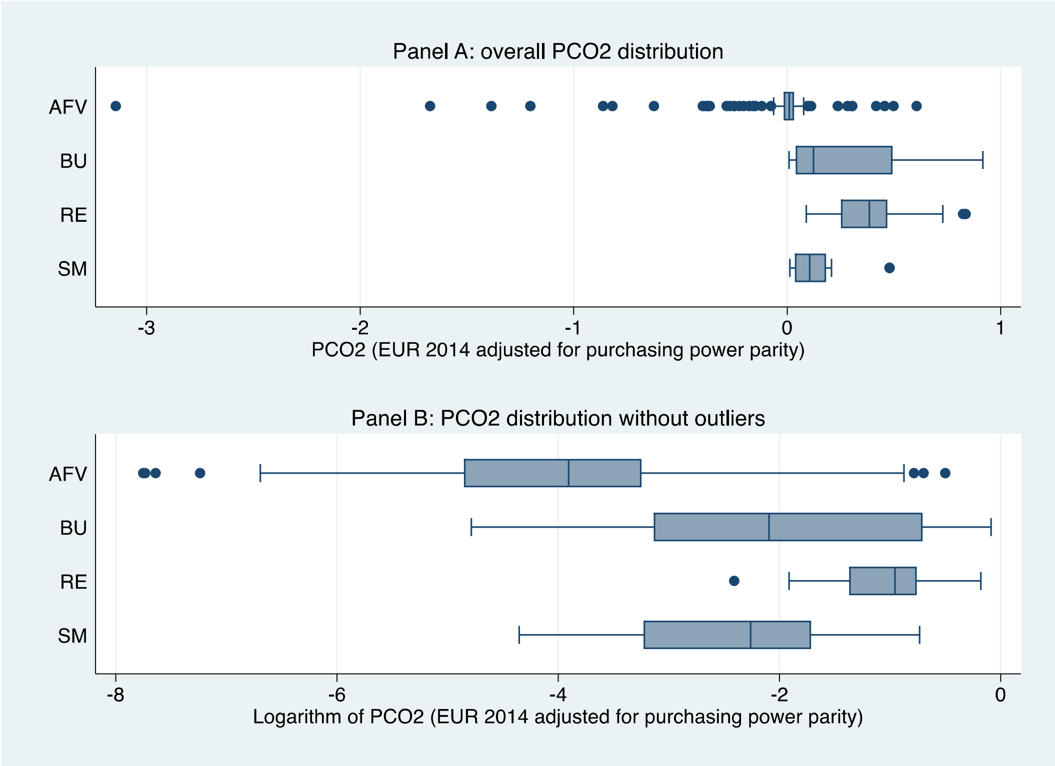

Fig. 1 Box plot of PCO2 distribution by GT

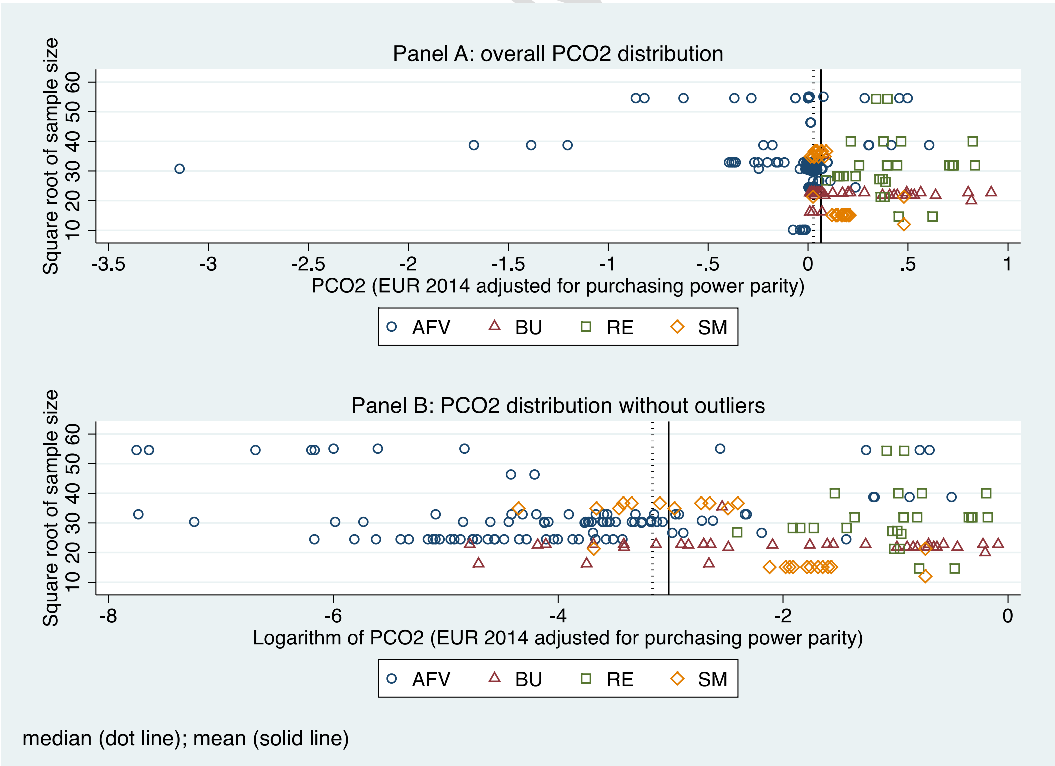

Fig. 2 Funnel plot of PCO2 distribution by GT

Table 1
Studies features and primary information.

Studies	Year[1]	Country	Period[2]	Sample[3]	GTs[4]	Observations[5]
Banfi et al.	2008	Switzerland	2003	517	BU	*16*
Kwak et al.	2010	Korea	2008	509	BU	*4*
Farsi	2010	Switzerland	2003	264	BU	*3*
Kesternich	2010	Germany	2009	1257	BU	*1*
Alberini et al.	2013	Switzerland	2010	473	BU	*2*
Achtnicht and Madlener	2014	Germany	2009	400	BU	*1*
Zalejska-Jonsson	2014	Sweden	2012	477	BU	*8*
Kaufmann et al.	2013	Switzerland	2010	144	SM	*1*
Gerpott and Paukert	2013	Germany	2011	453	SM	*2*
Pepermans	2014	Netherlands	2011	228	SM	*10*
Rihar et al.	2015	Slovenia	2013	1216	SM	*5*
Ida et al.	2014	Japan	2011	1343	SM	*6*
Hidrue et al.	2011	USA	2009	3029	AFV	*10*
Hackbarth and Madlener	2013	Germany	2011	711	AFV	*10*
Hoen and Koetse	2014	Netherlands	2011	103	AFV	*9*
Potoglou and Kanaroglou	2007	Canada	2005	902	AFV	*10*
Mabit and Fosgerau	2011	Denmark	2007	2146	AFV	*2*
Achtnicht	2012	Germany	2007	598	AFV	*32*
Koetse and Hoen	2014	Netherlands	2011	940	AFV	*6*
Axsen et al.	2009	Canada	2006	944	AFV	*5*
Helveston et al.	2015	USA	2013	1082	AFV	*28*
Bočkarjova et al.	2013	Netherlands	2012	2977	AFV	*15*
Dimitropoulos	2014	Netherlands	2012	1501	AFV	*9*
Dagsvik et al.	2002	Norway	2001	922	AFV	*24*
Bigerna and Polinori	2012	Italy	2007	1600	RE	*1*
Bigerna and Polinori	2013	Italy	2007	1600	RE	*1*
Bigerna and Polinori	2014	Italy	2007	1019	RE	*8*
Kim et al.	2012	Korea	2010	720	RE	*1*
Grösche and Schröder	2011	Germany	2008	2948	RE	*2*
Zoric and Hrovatin	2012	Slovenia	2008	450	RE	*2*
Yoo and Kwak	2009	Korea	2006	800	RE	*4*
Ivanova	2005	Australia	2004	213	RE	*2*
Batley et al.	2000	U.K	1999	742	RE	*1*
Batley et al.	2001	U.K	1997	746	RE	*2*
Bollino	2009	Italy	2007	1601	RE	*2*

[1] Year of publication. [2] Period of survey. [3] Sample size in primary studies. [4] Green technologies: energy savings in the building sector (BU), smart meters (SM), alternative fuel vehicles (AFV), renewable electricity (RE).
[5] Number of primary information provided by each primary study.

Table 2
PCO2 descriptive statistic by study (EUR 2014, PPP[1])

Studies	Year[2]	Obs.[3]	PCO2 Mean	St. dev
Banfi et al.	2008	*16*	*0.240*	*0.294*
Kwak et al.	2010	*4*	*0.092*	*0.069*
Farsi	2010	*3*	*0.034*	*0.032*
Kesternich	2010	*1*	*0.079*	--
Alberini et al.	2013	*2*	*0.058*	*0.036*
Achtnicht and Madlener	2014	*1*	*0.817*	--
Zalejska-Jonsson	2014	*8*	*0.479*	*0.084*
Kaufmann et al.	2013	*1*	*0.480*	--
Gerpott and Paukert	2013	*2*	*0.253*	*0.322*
Pepermans	2014	*10*	*0.168*	*0.030*
Rihar et al.	2015	*5*	*0.041*	*0.027*
Ida et al.	2014	*6*	*0.057*	*0.023*
Hidrue et al.	2011	*10*	*0.019*	*0.038*
Hackbarth and Madlener	2013	*10*	*0.058*	*0.039*
Hoen and Koetse	2014	*9*	*-0.032*	*0.022*
Potoglou and Kanaroglou	2007	*10*	*0.012*	*0.006*
Mabit and Fosgerau	2011	*2*	*0.013*	*0.002*
Achtnicht	2012	*32*	*0.019*	*0.046*
Koetse and Hoen	2014	*6*	*-0.018*	*0.019*
Axsen et al.	2009	*5*	*-0.642*	*1.405*
Helveston et al.	2015	*28*	*-0.078*	*0.158*
Bočkarjova et al.	2013	*15*	*-0.123*	*0.409*
Dimitropoulos	2014	*9*	*-0.337*	*0.862*
Dagsvik et al.	2002	*24*	*0.025*	*0.014*
Bigerna and Polinori	2012	*1*	*0.378*	--
Bigerna and Polinori	2013	*1*	*0.465*	--
Bigerna and Polinori	2014	*8*	*0.561*	*0.211*
Kim et al.	2012	*1*	*0.090*	--
Grösche and Schröder	2011	*2*	*0.369*	*0.040*
Zoric and Hrovatin	2012	*2*	*0.373*	*0.013*
Yoo and Kwak	2009	*4*	*0.180*	*0.041*
Ivanova	2005	*2*	*0.539*	*0.120*
Batley et al.	2000	*1*	*0.358*	--
Batley et al.	2001	*2*	*0.381*	*0.009*
Bollino	2009	*2*	*0.519*	*0.431*

Note. [1]*PPP purchasing power parity.* [2]*Year of publications.* [3]Nr. of primary information for each primary study

Table 3
PCO2 descriptive statistic (EUR 2014, PPP[1])

Sample	Obs.	Mean[2]	St. Dev.
Overall	245	0.065	0.377
By Green Technology			
Alternative Fuel Vehicle	160	-0.068*	0.389
Energy Savings in the Building Sector	35	0.262*	0.268
Smart Meters	24	*0.134*	0.124
Renewable Electricity	26	0.418*	0.208

Note. [1]*PPP, purchasing power parity.* [2]Significant differences between a group's means value and the mean of the reference group are statistically explored by t-test. Reference mean value is reported in italics. *Sig. at 5%, **sig. at 10%.

Table 4

Studies (primary information) and PCO2 descriptive statistics (EUR 2014, PPP[1])

Panel A: By continents and GTs[2]				
	AFV	BU	SM	RE
Asia	1 (14)	1 (4)	1 (6)	1 (5)
Europe	8 (111)	6 (31)	4 (18)	8 (19)
North America	4 (39)			
Oceania				1 (2)
Panel B: By Continent				
Continent	GTs[1]	Obs.	Mean[3]	St. dev.
Asia	AFV/BU/SM/ RE	29	*0.042*	0.102
Europe	AFV/BU/SM/ RE	179	0.101*	0.338
North America	AFV	39	-0.185*	0.627
Oceania	RE	2	0.539	0.120
Panel C: For most representative countries				
Country	GTs[1]	Obs.	Mean	St. dev.
Germany	AFV/BU/SM/ RE	48	0.070	0.160
Netherlands	AFV/SM	49	-0.081	0.478
Slovenia	RE /SM	7	0.136	0.164
Switzerland	BU/SM	22	0.207	0.270
USA	AFV	25	-0.109	0.178
California	AFV	6	-0.246	0.213
Korea	BU/ RE	9	0.131	0.068

Note. [1]PPP, purchasing power parity. [2]Green technologies: alternative fuel vehicles (AFV), energy savings in the building sector (BU) smart meters (SM), renewable electricity (RE).

[3]Significant differences between a group's means value and the mean of the reference group are statistically explored by t-test. Reference mean value is reported in italics. *Sig. at 5%, **sig. at 10%. Oceania excluded.

Table 5

Studies (primary information) and PCO2 descriptive statistics (EUR 2014, PPP[1])

Panel A: By year of publication and GTs[2]				
Year/GTs	AFV	BU	SM	RE
2000				1 (1)
2001				1 (2)
2002	1 (24)			
2005				1 (2)
2007	1 (10)			
2008		1 (16)		
2009	1 (5)			2 (6)
2010		3 (8)		
2011	2 (12)			1 (2)
2012	1 (32)			3 (4)
2013	2 (25)	1 (2)	2 (3)	1 (1)
2014	3 (24)	2 (9)	2 (16)	1 (8)
2015	1 (28)		1 (5)	
Panel B: Pre and post crisis				
Years	GTs	Observations	Mean[3]	St. dev.
2000 - 2007 (pre-crisis)	AFV/ RE	39	0.088*	0.159
2008 - 2015 (post crisis)	AFV/BU/SM/ RE	206	*0.061*	0.400

Note. [1]PPP, purchasing power parity. [2]Green technologies (GTs): alternative fuel vehicles (AFV), energy savings in the building savings (BU), smart meters (SM), renewable electricity (RE). [3]Significant differences between a group's means value and the mean of the reference group are statistically explored by t-test. Reference mean value is reported in italics. *Sig. at 5%, **sig. at 10%.

Table 6
Variables description, summary statistics and PCO2 conditional statistics[1] (EUR 2014, PPP[2]).

Variable	Description	Mean	St. dev.	*Mean*	*St. dev.*
LHS					
ln(PCO2)[3]	Logarithm of PCO2	--	--	*1.098*	*0.999*
RHS					
MentCo2	= 1 if CO2 reduction is explicitly mentioned to the respondents	0.186	0.390	*0.275*	*0.252*
Scenario features					
SceGen	= 1 if a generic scenario is proposed to the respondents	0.486	0.501	*0.068*	*0.401*
WTPdu	= 1 if the WTP is with no specified duration	0.200	0.401	*0.178*	*0.508*
WTPop	= 1 if the WTP is one-time payment	0.636	0.482	*0.305*	*0.252*
WTPan	= 1 if the WTP is per year	0.191	0.394	*-0.056*	*0.411*
WTPmo	= 1 if the WTP is per month	0.164	0.371	*0.040*	*0.368*
Context features					
Deu	= 1 if the study is conducted in European countries	0.741	0.439	*0.104*	*0.336*
Dasia	= 1 if the study is conducted in Asian countries	0.132	0.339	*0.042*	*0.102*
Dnam	= 1 if the study is conducted in North-American countries	0.118	0.324	*-0.189*	*0.625*
D2008	= 1 if the study is published after January 1st, 2008	0.855	0.353	*0.061*	*0.400*
Socio-economic features					
Income	Income per capita per month (EUR 2014, PPP)	3443.15	902.10	--	--
Hous	= 1 if the respondents are households	0.218	0.414	*0.290*	*0.235*
Indiv	= 1 if the respondents are individuals	0.745	0.437	*-0.001*	*0.392*
Owner	= 1 if the respondents are owners	0.350	0.478	*-0.054*	*0.386*
Equipment features					
DurG	= 1 if the evaluation regards durable goods	0.773	0.420	*0.002*	*0.387*
NDurG	= 1 if the evaluation regards no durable goods	0.105	0.307	*0.138*	*0.125*
Services	= 1 if the evaluation regards services	0.118	0.324	*0.418*	*0.208*
Dafv	= 1 if the evaluation regards AFV	0.614	0.488	*-0.066*	*0.385*
Dbu	= 1 if the evaluation regards BU	0.159	0.367	*0.262*	*0.268*
Dsm	= 1 if the evaluation regards SM	0.109	0.312	*0.134*	*0.124*
Methodological features					
Sample	number of respondents	1012.29	739.42	--	--
Dbigs	= 1 if the size of sample used in the primary study is > 1082	0.218	0.414	*-0.031*	*0.481*
Dsmalls	= 1 if the size of sample used in the primary study is < 322	0.259	0.439	*0.235*	*0.244*
Quantile	ordered variable ranging from 1 to 4.	2.377	1.093	--	--
Dftof	= 1 if the surveys are conducted face to face	0.295	0.457	*0.037*	*0.054*
Dmail	= 1 if the surveys are conducted via mail	0.077	0.268	*0.389*	*0.188*
Dweb	= 1 if the surveys are conducted online	0.409	0.493	*0.023*	*0.522*
Dmixsur	= 1 if the surveys are conducted using more than one method	0.145	0.353	*-0.017*	*0.240*
Dwta	= 1 if WTP is negative	0.164	0.371	*-0.392*	*0.621*
Ddb	= 1 if the valuation question has an dichotomous format	0.082	0.275	*0.122*	*0.125*
Doe	= 1 if the valuation question has an open-ended format	0.077	0.268	*0.498*	*0.198*
Dce	= 1 if the valuation question format is choiche experiment	0.841	0.367	*0.020*	*0.378*

Note. [1]Last two columns show PCO2 mean and st. dev. if the dummy variable in the corresponding row is equal to 1. [2]PPP, purchasing power parity. [3]We have handled data adding a constant equal to min value of PCO2.

Table 7
Meta-regression results and clustered standard errors LHS = ln(PCO2)

Variables	Coef.	
MentCO2	3.751	
	(1.284)	*
	[0.436]	*
SceGen	3.156	
	(0.815)	*
	[0.383]	*
WTPdu	-1.343	
	(0.788)	**
	[0.517]	*
WTPop	-1.253	
	(0.741)	**
	[0.455]	*
Deu	4.600	
	(0.900)	*
	[1.087]	**
Dnam	-5.028	
	(1.625)	*
	[2.830]	
D2008	-1.491	
	(0.866)	**
	[0.447]	*
Income	0.002	
	(0.000)	*
	[0.000]	*
Indiv	-0.366	
	(2.062)	
	[1.789]	
Dsm	1.311	
	(3.927)	
	[2.313]	
Dbu	0.305	
	(1.478)	
	[1.106]	
NDurG	0.177	
	(3.616)	
	[6.438]	
DurG	-2.339	
	(1.054)	*
	[1.278]	**
Dmixsurv	3.463	
	(0.961)	*
	[0.454]	*
Dftof	1.149	
	(1.261)	
	[0.433]	*
Quantile	-0.012	
	(0.181)	
	[0.137]	
Ddb	1.268	
	(0.719)	**
	[1.320]	
Dwta	-2.223	
	(0.812)	*
	[0.496]	*
Cons	-5.731	
	(3.300)	**
	[1.139]	*
Number of obs = 220; Adj R-squared = 62.78%; Model F(18, 201) = 4.84; Prob > F = 0.0000		

Note. Standard errors clustered by study are reported in brackets. Robust standard errors are reported in parentheses. Statistical significance at the * 5%, ** 10% level.