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

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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. 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[1] 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

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.

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[1] 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).

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and energy behaviors (Martos et al., 2016).

According to this scenario, we have selected four green technologies[2] (GTs): alternative fuel vehicles[3] (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[4] 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 1 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, 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[5].

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 (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"

[2] 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).

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

[4] 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.

[5] 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.