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Revealed and stated preferences for CO_2 emissions reduction: The missing link

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A B S T R A C T

In this paper we combine data collected from two strands of literature dealing with revealed preferences expressed by conventional vehicle drivers for fuel price variation and stated preferences expressed by consumers for alternative fuel vehicles. We employ a meta-analysis approach drawing data on 30 primary studies, reflecting two important policy interventions, which are fuel price taxation and subsidies for alternative fuel vehicles. This is a new contribution in environmental and energy economics in that we rescale all primary information into a unique index, which captures consumers' economic attitude towards carbon dioxide (CO_2) emission reduction in monetary terms. Focusing on the transport sector, we compute the implicit price for the avoidance of a kilogram of CO_2 emissions, named PCO_2, explaining the existing heterogeneity from several points of view. The results of the meta-analysis show that contextual and individual characteristics influence the implicit price for CO_2 emissions avoidance. This implicit price is on average positive in the case of revealed preferences studies, whereas it is negative in the stated preferences studies. Although there are some important geographical differences, our results show that fuel taxes could be an important additional instrument for environmental policy.

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1. Introduction

The reduction of carbon dioxide (CO_2) emissions is imperative for climate change mitigation. Global energy-related emissions of CO_2 reached 31.6 gigatonnes in 2012, with an increase of 1.2% compared with 2011. The transport sector is currently responsible for 23% of global energy-related CO_2 emissions from oil-based fuel combustion, with the road transport sector showing the greatest burden. The share in the total energy demand of transport is

Abbreviations: AFV(s), alternative fuel vehicle(s); BRIC, acronym for four major emerging national economies: Brazil, Russia, India and China; CO_2, carbon dioxide; LHS, left-hand side; OLS, ordinary least square; PCO_2, implicit price for CO_2 emissions avoidance; RHS, right-hand side; RP, revealed preferences; SP, stated preferences; WLS, weighted least square; WTA, willingness to accept; WTP, willingness to pay

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expected to increase from the current 55% to over 60% in 2040 [1]. There are several environmental policies to reduce emissions and become a low-carbon society in the field of transport. To mitigate emissions, the consensus Scenario[1] sets a challenging target for the transport sector, which should contribute to a 16% CO2 emissions reduction by 2040 [2].

The aim of this paper is to assess consumers' attitude in monetary terms toward the avoidance of CO_2 emissions in the transport sector, by comparing information on consumers' response to two main stream of policy interventions, i.e., traditional fuel price taxation and the promotion of alternative fuel vehicles (AFVs). Our research question is whether both the normal car driver and the environmentally conscious driver have similar or different attitudes towards the reduction of vehicle emissions. For the empirical estimation, we use meta-analysis, which is a useful method for integrating quantitative data from multiple studies.

The first policy intervention is traditional fuel price taxation to induce fuel consumption reduction and/or purchasing of high efficiency vehicles. Fuel taxation is unpopular among consumers, implying a limited recourse to this tool by policy makers. In any case, even if fuel taxes were not originally designed for environmental purposes but rather as financing tools for highway construction and maintenance directly benefitting the drivers, they also have an effect on improving the environmental quality [3,4]. Indeed, in European countries, the long-run policy of high taxes since the 1970s raised the consumer price by a factor of approximately three, cutting CO2 emissions by more than half [5]. If the United States and other industrial countries had adopted a policy similar to Europe, the CO2 in the atmosphere would have been lower than that today [6]. In addition, non-economic and cultural factors such as lifestyle, educational scheme and other government initiatives make a small but important contribution in changing transport fuel demand [7].

The second policy intervention is focusing on the promotion of AFVs, including battery electric vehicles, hybrid electric vehicles and plug-in hybrid electric vehicles. The most common policy instruments used to accelerate AFVs' developments are constituted by vehicle purchase subsidy and infrastructural investments. There has been little focus in the literature on the comparison between traditional and innovative policy interventions [8,9]. To pursue further this topic, we have examined two types of primary sources in the literature, both dealing with the problem of measuring and assessing consumer preferences for energy and environmental policies.

We have gathered a complex body of knowledge from the literature, combining information about revealed preferences (RP) for traditional means of emission reduction, such as a policy intervention on the fuel market price, and information about stated preferences (SP) for new low emission technology, such as AFVs. In other words, we compare consumers' attitudes toward the additional taxation necessary to obtain lower fuel consumption and therefore lower CO_2 emissions with the equivalent additional capital expenditure for new AFVs. Through a rescaling procedure, we compute the implicit price for avoiding a kilogram of CO_2 emission, named PCO_2, obtaining a specific measure in monetary terms for avoiding polluting vehicle emissions[2].

In the case of RP, we consider elasticity of demand for gasoline, which arise from estimation of actual market behavior. In the case of SP, we consider expected future choice behavior for AFVs [10]. Operationally, we have collected different data, which are not immediately tangible, we have transformed them into structured knowledge and classified objects having distinctive patterns of attributes into specific categories [11]. Then, we have rescaled all the primary data in the unique index PCO_2. Finally, we have dealt the heterogeneity of PCO_2 with the meta-regression analysis.

The novelty of our approach is that we assess the degree of possible deployment of different technologies, combining data from RP and SP through the meta-analysis. Indeed, meta-analysis can represent an appropriate technique in order to study the value of CO_2 emissions reduction, given that it can summarize the results of very heterogeneous studies in SP framework [12]. Combining RP and SP data can exploit their strengths, recovering sufficient information for economic analysis [13]. It should be stressed that SP values are higher than RP values, because they reflects the consumers' surplus and the highest value of WTP. We explain why these differences occur, contributing to the literature that addresses this issue [14].

We deem that explicitly modeling consumer utility for emission reduction can encompass a fruitful analysis of consumers' attitudes in monetary terms for avoiding CO_2 emissions, either in the case of a positive attitude toward new environmentally friendly technologies or in the case of compulsorily enforcement of additional taxation of the fuel price.

The paper is organized as follows. Section 2 describes the materials and methods. Section 3 presents the results and discussion. Finally, Section 4 draws conclusions.

2. Materials and methods

2.1. Literature search

There is rising interest in the literature for combining RP and SP also in environmental economics in order to evaluate the effects of climate change[3], as these two methods are complementary ways of investigating the same choice problem [19]. In this paper, a systematic literature search has been conducted to find articles investigating consumers' demand elasticities for gasoline consumption and consumers' perception and attitudes towards AFVs.

The early research on gasoline demand to understand the dynamics of gasoline consumption and vehicle use was carried out particularly during the 1970s and 1980s, following the 1973 energy shock price[4]. These studies were mainly motivated by concerns about the availability of sufficient depletable resources. Interest in gasoline demand re-emerged in the literature in the 1990s due to the environmental commitments of the Kyoto Protocol. Therefore, we focus on papers published after the Kyoto Protocol. Several studies have addressed the environmental consequences of gasoline consumption, thus investigating gasoline demand elasticities [20–22]. The majority of studies on gasoline

[1] The World Energy Outlook 2015 consensus Scenario is called the "450 Scenario" because it has the target of stabilizing the CO_2 concentration in the atmosphere at the level of 450 ppm. This Scenario assumes a set of policies that limit the rise in long-term average global temperature to two degrees Celsius [1].

[2] In other words, we compare consumers' attitudes toward the additional taxation necessary to obtain lower fuel consumption and therefore lower CO_2 emissions with the equivalent additional capital expenditure for new AFVs.

[3] So far, the integration of RP and SP data has occurred mainly in the fields of transportation [15,16] and marketing [10,17]. For example, in the marketing field Neelamegham and Jain [18] explore consumers' choice process for experience goods, finding that psychological variables, such as consumers' expectations and latent product interest, strongly influence choice and post-choice behaviors.

[4] High fuel prices in the period 1973-1985 resulted in lower vehicle usage, whereas vehicle usage started to rise afterwards when the real fuel prices fell in most of the *Organisation for Economic Co-operation and Development* countries. As a result, the United States were the highest per capita CO_2 emitters in 1992 (3.80 ton of CO_2/per capita), followed by the European Union (seven countries) (1.41 ton of CO_2/per capita) and Japan (1.13 ton of CO_2/per capita).

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