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Consumer-side actions in a low-carbon economy: A dynamic CGE analysis for Spain

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ABSTRACT

In recent decades, the need to strengthen efforts to reduce GHG emissions to combat Climate Change has become a major global concern, as reflected in the 2015 Paris Agreement and the EU Climate strategy (2016). In this context, EU countries are required to organize their contributions to environmental improvement through national strategies. Given the potential importance of demand-side actions, both directly and through their relationship with the productive system, as well as the need for a dynamic evolution, we assess the dynamic path and medium-term environmental impact of certain consumer-oriented measures, using a dynamic Computable General Equilibrium (CGE) model. Specifically, we generate scenarios that follow Spain's strategies and evaluate the dynamic impact of more efficient technologies on electricity consumption and the use of transport services, both in terms of environmental (GHG and SO_x) and economic effects. Our results confirm the role of technology improvements in delivering positive results for the environment, and the importance of economy-wide rebound effects, through a detailed study of energy uses as a result of efficiency improvements in household energy consumption. Our findings show that reductions in emissions per person are consistent with economic growth.

1. Introduction

In recent decades, developed countries have made important investments in technology aiming to increase energy efficiency, both in productive activities and in energy use by households. Most of the electrical appliances sold today in Europe offer significant improvements in energy efficiency, and the promotion of public transport systems with greater fuel efficiency has played a prominent role in institutional environmental campaigns at the national and international levels. The EU climate strategy, EU (2016), aims to achieve an economy-wide GHG reduction target of at least 20% by 2020, compared to 1990, 40% by 2030, and 80% by 2050, and has set emissions ceilings for 2020 for each European Union (EU) member state (Directive, 2012/27UE), under which countries are required to organize their contributions to environmental improvement through national strategies.[1] In this context, the goal of Spain's current Energy Efficiency Action Plan (2014–2020) (NEEAP, 2014–2020) is to reduce energy consumption – and thus greenhouse gas (GHG) emissions – by 20% by 2020, following the methodological recommendations on savings, measurement, and verification of the European Commission. The Spanish Plan has the objective of improving final energy intensity by around 2% year-on-year for the period 2010–2020, focusing efforts on six sectors of the economy (Industry, Transport, Building (residential and service), Equipment (residential and service), Public Services, and Agriculture and fisheries), with specific measures for each of the direct, indirect, and end-users involved. The objectives for 2030 will be designed under a new Plan in line with the goals of the EU.

An important part of the discussion in the literature has focused on the effects of technology and efficiency improvements implemented on the production side, rather than the consumer side. However, there is an increasing recognition that the responsibility for atmospheric emissions is not solely associated with producers, but also with the end-users of goods (Lenzen et al., 2007; Wiedmann et al., 2007, Hubacek et al., 2014; Cadarso et al., 2015; Hubacek et al., 2016; Feng and Hubacek, 2016; Schandl et al., 2016). Consumer actions have effects on production and related emissions, and thus a key question emerges: can gradual changes in household consumption patterns produce significant impacts on total emissions in the medium-term? We aim to address this question, looking at 2030.

More specifically, we assess the medium-term (up to 2030) environmental impact on the Spanish economy of certain consumer-oriented measures that are consistent with proposals of the Spanish

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[1] The EU´s emissions for 2005 are slightly lower than those of 1990, and we use emissions in 2005 as the reference point, in line with EU targets.

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"Energy Efficiency Action Plan", exploring representative dynamic scenarios for a longer period, 2005–2030, and involving individual consumers. Hence, we analyse the impact of successive improvements, up to 2030, in household electricity savings (for lighting per dwelling and electrical appliances) and the promotion of efficient modes of transport (lower-fuel-consumption vehicles). We aim to test whether it will be possible to achieve the 2030 EU objectives, which focus on an energy consumption reduction of 40% or more.

A dynamic framework is essential in order to better capture the transition towards 2030 targets, the medium-term rebound effects, and their evolution over time. Our work uses a recursive dynamic Computable General Equilibrium (CGE) model, calibrated on 2005 Spanish data and dynamically extended for the period 2005–2030. We assume that the generalization of the implementation of improvements among citizens from 2005 to 2030 is low in the initial period, with a temporal progression characterized by an intermediate acceleration and smooth growth after a certain number of periods. We thus propose (as a novelty in the literature) a logistic schedule to capture this gradual adaptation. Moreover, this evolution is based on the real evolution of energy use from 2005 to 2015.

CGE models are multi-sector macroeconomic tools, used to simulate the ultimate result of such improvements, allowing us to capture changes in prices, investment, consumption, production, trade, and technology. Using a dynamic CGE model, we can also evaluate the time-consistency of environmental outcomes and the socio-economic (unemployment, welfare, production) effects of potential consumption choices of citizens.

Additionally, this work aims to contribute to the literature on rebound effects with a dynamic extension, given that, to the best of our knowledge, this is the first work to empirically measure the rebound effects associated with a logistic evolution of the improvements in the efficiency of household energy use. We also explore whether emissions related to household energy savings are compensated over time by potential spending of the additional income available from reductions in energy consumption.

From an empirical point of view, our analysis focuses on Spain, a middle-income ranked EU Member State, and on greenhouse gases (GHG) and sulphur oxide (SO_x).[2] We present the evolution and trends obtained from a dynamic model that considers the behaviour of more than 44 million people (the Spanish population) that can be highly representative of the gradual adaptation of consumers to new challenges for sustainable development in a wide range of developed countries.

In summary, this paper presents a full study of the implications of successive changes in consumption patterns, in terms of environmental and economic impacts for the whole economy (household and industrial uses of energy, rebound effects, jobs, macroeconomic results, GHG and SO_x emissions) with a global view of impacts. In other words, we address the following general question: To what extent could successive environmentally-positive changes in household consumption patterns lead to a large reduction of emissions in society as a whole, thus meeting environmental mandates?

The rest of the paper is organized as follows. Section 2 presents a brief review of prior work in this area. Section 3 sets out our methodology and data. Section 4 describes the 2005 pollution structure of the Spanish economy, our simulations, and the results obtained. Section 5 addresses sensitivity analyses of different assumptions for technological change, emissions data, and elasticity of substitution. Finally, Section 6 closes the paper with our concluding remarks.

2. Literature review

Alongside the input-output literature on carbon emissions and environmental footprints, which mainly recognize the multi-sectoral nature of environmental impacts and the links between the consumption and the production perspectives (see for instance Lenzen et al., 2007; Wiedmann et al., 2007; Hubacek et al., 2014; and Duarte et al., 2010; Cadarso et al., 2015 for Spain, amongst others), CGE models have also been developed to assess the environmental impacts of consumption patterns, which allow for greater flexibility in modelling consumer behaviours and price reactions, as well as the capture of potential rebound effects. For instance, Dai et al. (2012) examine impacts on total energy use and emissions from changes in consumption patterns of Chinese households from high fossil fuel and carbon-intensive behaviour, to low fossil fuel and carbon-extensive behaviour towards 2050, using a dynamic CGE model. They reveal the importance of paying attention to demand-side countermeasures. Lecca et al. (2014) explore the rebound effects of increased energy efficiency in the household sector of the United Kingdom. Their results show a net expansion in the UK economy, with increases in investment, employment, and household spending. Duarte et al. (2016) use a static CGE model calibrated for Spain, and evaluate the effects of changes in the environmental awareness of Spanish consumers of different income levels. Their results suggest that reductions in emissions may be compatible with increases in income and reductions in unemployment. Figus et al. (2016) analyse the economy-wide impacts of improvements in Scottish household energy efficiency that lead to stimulation of the economy of the region. Tian et al. (2016) investigate the effects of household consumption pattern for a mega-city in the developing world, employing a CGE for the Shanghai economy. Figus et al. (2017) analyse the sustained added value to the UK economy by improving energy efficiency in the residential sector through government support at different income levels.

In the context of this literature, our paper is, to the best of our knowledge, the first study to evaluate changes in consumption choices and their gradual adaptation by citizens, in terms of emissions, using a logistic evolution. The use of logistic curves provides S-shaped patterns, which have been widely used in the literature to model different processes of innovation diffusion (Mansfield, 1961; Mahajan and Peterson, 1985; Kijek and Kijek, 2010). Our work involves a new use of these functions to approximate to the generalization of improvements among citizens that is low at the outset, with a temporal progression characterized by an intermediate acceleration and smooth growth after a certain number of periods (S-shaped pattern). This assumption allows us to achieve a better approximation of the effects of the generalization of improvements, an evaluation of the rebound effects triggered by technical change, and a greater understanding of economy-wide impacts and their evolution. Thus, our work benefits from the prior literature, and attempts to go further into the analysis of changes in consumption, in electricity use, and in the transport sector, through a dynamic CGE model that includes technological progress as a logistic evolution, to capture the gradual adaptation of citizens to policy targets.

The rebound effect has been broadly studied via CGE models, finding evidence that these effects may reduce the positive environmental results of efficiency improvements (see Hanley et al., 2006; Anson and Turner, 2009 for Scotland, using a dynamic CGE model; Barker et al., 2007 for the UK economy; Barker et al., 2009 for the world economy; Turner and Hanley, 2011 for the Scottish economy, and Koesler et al., 2016 for the global economy). Our work follows the recent rebound measures proposed in Lecca et al. (2014) and Koesler et al. (2016) to measure the economy-wide rebound effects of logistic improvements in the efficiency of household energy use.

3. Methodology

A dynamic CGE model is developed for the Spanish economy and calibrated using the Spanish Input-Output Framework (symmetric IOFA-05) available from INE (2005a). This section outlines the model

[2] We also analyse impacts on SO_x emissions due to their local effects, to approximate better to the regional impact.