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Households energy consumption and transition toward cleaner energy sources☆

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ABSTRACT

The paper investigates the factors influencing households' energy choices, and the drivers of switching toward cleaner energy. We first present a theoretical framework to determine the factors that explain households' energy consumption and highlight the motivations underlying their transition towards less polluting sources, including their environmental preference. Using French household data from ADEME, we provide an econometric test of qualitative variables following studies by Dubin and McFadden (1984). Our results show that income and prices are the main determinants of household energy consumption. Environmental considerations seem to influence the choice of energy sources more than consumption. We also find evidence that income and relative capital cost are the most important variables for household energy switching.

1. Introduction

Mitigation on climate Change implies important transition of our energy consumption, both in terms of quantities and in terms of energy sources. Many countries, such as France and Germany, have implemented policies and strategies to encourage cleaner energy consumption and greater energy efficiency. In France, the energy transition law for green growth (LTECV) enacted in 2015 moves in this direction. In Germany, the renewable energies act (EEG) was adopted in 2000 and reviewed in 2016. These various actions aim to reduce greenhouse gas emissions by 40% by 2030 for France and by 2020 for Germany compared to 1990. In addition, France is also planning to increase the share of renewables energy from 14.9% today to 32% and to reduce its final energy consumption, estimated at 162 Mtoe, by 20% by 2030.

In France, for instance, the building sector is the largest energy consumer with 44%, of which two-thirds is attributed to the residential sector which represents more than 20% of national CO_2 emissions (ADEME, 2014a, 2014b). The average of final energy consumption in the residential sector amounts to 68.28 Mtoe between 2005 and 2014. It is relatively stable since 2005 and is still dominated by fossil fuels, with 16.6% for fuel oil and 28.9% for gas (see Appendix, Fig. 5).

Overall, the residential sector has great potential for GHG emissions reduction, that public policies are aiming to exploit. In order to make the best of this potential, determining the variables explaining household energy consumption and the factors underlying their transition to cleaner sources is crucial. Several studies have focused on household energy consumption. However, most of them assume that the discrete choices made by households are linked to continuous choices. For example, a household's decision to choose an energy source i (discrete) will also depend on the energy quantity qi to be consumed. Dubin and McFadden (1984) propose for the first time a discrete/continuous choice model to capture this interdependence. Following them, other authors have applied this type of model (Bernard et al., 1996; Vaage, 2000). Nesbakken (2001) considers that discrete and continuous choice does not occur during the same period.[2] Couture et al. (2012) focus on French households' fuel wood consumption, considering the type of wood use as the main or a secondary energy source.[3] They show that, the choice of wood as the main source of heating energy is negatively

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[2] Indeed, his idea is that many households do not explicitly choose the heating system, because this choice is made at the time of house building, whereas the energy quantity choice is made in the current period, after households take up residence.

[3] These authors variously consider individuals who don't use wood (non-users), wood users for the main energy source, and those who use it for back-up heating.

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linked to income, and the price of wood doesn't seem to affect wood choice probability for any use. However, household fuel wood demand may also be affected by location[4] (Aguilar et al., 2012a, 2012b). Fateh (2016) focuses on residential energy consumption in France and shows that occupant characteristics significantly affect domestic energy use.

From another angle, Christian and Reinhard (2016) investigate drivers and barriers behind decisions of homeowners in Germany to switch from a fossil fuel to a renewable heating system.[5] They show that environmental protection, low dependence to fossil fuels and knowledge about heating systems are the main determinants of switching from fossil fuels to renewable energy sources. The obstacles are the difficulty of getting used to the system and failure to understand its functioning, the maintenance costs (for example sweeping and cleaning).

Overall, the energy consumption literature has mainly focused on socio-economic factors, demographic characteristics, housing types, etc. To our knowledge, household environmental preferences haven't yet been taken into account in energy choice and consumption. Nevertheless, opinions on the negative effects of energy consumption require the incorporation of environmental sensitivity into the analysis of individual behaviors in terms of energy consumption.

The contribution of this paper is twofold. First, it makes a link between the literature explaining households' energy consumption choices and the literature investigating the drivers of transition towards less polluting sources. Indeed, it is of interest to investigate how the choice of energy source influences energy consumption behaviors. Second, it takes into account the households' environmental preference in their energy choice and consumption. In other words, what are the determinants of household energy consumption? What are the drivers behind the transition to cleaner energy sources? To address these questions, we use an original database, constructed on the basis of national surveys of energy use in France and the characteristics of households and dwellings, carried out by ADEME. This micro-economic database was partially used on investment decisions for household retrofits in a study by Nauleau (2014). This database (38,557 observations) presents several improvement to the ones used in previous studies. First, households from the whole country have been surveyed, while the households wood energy consumption survey (BVA survey institute, 2006), used by Couture et al. (2012) only covers the Midi-Pyrénées region. Second, the INSEE housing survey (used for instance in Emmanuel et al., 2017 or Fateh, 2016) only present data replying to energy consumption, but not on the choice of energy source. Finally, none of these database have information on household's environmental preference, capital costs and the household's switching decision.

Our empirical approach is based on a two-step method: a discrete/continuous choice model is used in the first step to analyze household energy consumption for all uses. First, we estimate the discrete model (multinomial logit model) by the maximum likelihood method. Second, the conditional demand for the chosen alternative is estimated by adding the bias correctors made in the step. We then use a binary logit model to analyze the switching probability for heating.

Section 2 presents the theoretical model of energy consumption and household switching decision. The econometric specification and empirical strategy are discussed in Section 3, while Section 4 describes the methodology and data used. The results from the econometric analysis are reported and discussed in Section 5. Section 6 presents the conclusion and discussion.

[4] For example, in the United States, households in different areas (urban / rural areas) consume wood energy at different levels. Indeed, the differences in levels of wood energy consumption may be due to differences in the availability and price of wood, as well as the household's intrinsic preferences.

[5] They use data from surveys of homeowners who changed their oil or gas heating systems for a new oil or gas boiler with solar thermal support, a heat pump or a wood pellet boiler between January 2009 and August 2010.

2. Theoretical framework

2.1. Households energy consumption

We consider a representative household choosing its energy consumption, maximizing utility subject to a budget constraint. The household first chooses the type of energy source it will use $i = 1, ...,I$, and then the quantity of energy q_i it will consume. Choosing a source of energy implies to invest in a durable good of initial value K_i. The durable good lasts for $\overline{T}$ periods. To keep simple, we assume that the household pays each period a share $s/\overline{T}$ of the initial value. Thus, the durable good is entirely paid when its residual value goes to 0, after $\overline{T}$ periods. We assume that there is no second market, so that a durable abandoned before its lifetime expires does not bring any additional revenue. The model is solved backward. Utility is increasing in energy consumption q_i and consumption of a composite good x, used as a numeraire. It is also decreasing in CO2 emissions, $E_i(q_i) = e_i q_i$, involved by the energy source i. e_i represents the emission factor of energy source i. We assume standard properties of the utility function: $U(q_i, x, E_i)$ is increasing and concave in q_i and x; and is decreasing and convex in $E_i(q_i)$: $U_{q_i} > 0$, $U_{q_i q_i} < 0$, $U_x > 0$, $U_{xx} < 0$, $U_{E_i} < 0$, $U_{E_i E_i} < 0$.

The household optimization problem is thus, at each period, to maximize utility:

$$\begin{aligned} \max_{q_i, x} \quad & U(q_i, x, E_i(q_i)) \\ s.\,t \quad & Y \geq p_i q_i + x + \frac{sK_i}{\overline{T}} \\ & E_i(q_i) = e_i q_i \end{aligned} \tag{1}$$

with Y the household's income and p_i the price of energy i.

First-order conditions implicitly give the optimal consumption of energy and of the composite good. $q_i^*(p_i, Y, K_i, s, e_i, \overline{T})$ and $x^*(p_i, Y, K_i, s, e_i, \overline{T})$ are implicitly given by:

$$\begin{aligned} \frac{U_{q_i} + e_i U_{E_i}}{U_x} &= p_i \\ p_i q_i^* + x^* + \frac{sK_i}{\overline{T}} &= Y \end{aligned} \tag{2}$$

Standard results arise from this first step: consumption of energy i is decreasing in its price, in the cost of the durable good and, increasing in income.

Result 1. consumption of a given energy source is decreasing in the household's environmental preferences (desutility from CO2 emissions). Similarly, for two different energy sources of same price, the household would tend to consume a larger amount of the cleaner energy source.

2.2. The energy switching

In the first stage, the household chooses its energy source, considering its optimal consumption of the second stage, given energy prices, income and the cost of the durable good. Moreover, at every period, they consider whether it is profitable to them to switch their source of energy.

The household can decide to switch from its initial energy source j to energy source i either at the end of the durable lifetime or before the end of the durable lifetime.

2.2.1. Switch at the end of the durable lifetime

When the durable good is entirely paid, and has no residual value, it is necessary to invest in a new durable. Households can switch their source of energy at no additional cost. Households choose energy source i over any other source of energy if it maximizes its expected discounted utility: