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Beyond average energy consumption in the French residential housing market: A household classification approach☆

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ABSTRACT

In a new environment marked by the growing importance of Green House Gas emissions, fuel poverty, and energy efficiency in the different national agendas, the comprehension of energy demand factors appears to be crucial for the effectiveness of energy policies. We consider the latter could be improved by targeting specific household groups rather than looking to follow a single energy consumption level target. This article explores the scope of having a disaggregated energy consumption market to design policies aimed at curbing residential energy consumption or lowering its carbon intensity. Using a clustering method based on the CHAID (Chi Square Automatic Interaction Detection) methodology, we find that the different levels of energy consumption in the French residential sector are related to socio-economic, dwelling and regional characteristics. Then, we build a typology of energy-consuming households where targeted groups (fuel poor, high income and high consuming households) are clearly and separately identified through a simple and transparent set of characteristics. This classification represents an efficient tool for energy efficiency programs and energy poverty policies, but also for potential investors, which could provide specific and tailor made financial tools for the different consumer groups. Furthermore, our approach helps designing some energy efficiency score that could reduce the rebound effect uncertainty for each identified household group.

1. Introduction

The tertiary sector, which includes the residential sector, represents about 44.9% of global energy consumption in France, and 21% of CO_2 emissions in 2015. This sector consumes more energy than any other sector in the country (33.1% for transport, 19% for industry, and 3% for agriculture). Within this sector, the residential part accounts for 67% (i.e., 30.2% of final energy consumption).[1] The residential sector is then considered as a key driver for energy efficiency programs—such as insulation—and more generally for energy policy. Despite this major role, energy efficiency policy measures have been either designed to fit an average national target or restricted to a small portion of the population. In France, energy efficiency social benefit programs exist for modest landlords in old dwellings (National Housing Agency programs), but there is no specific policy devoted to other income groups. Instead, wide-ranging policies, such as subvention programs (zero interest rate loans) or tax cuts (tax credit for sustainable development and energy transition), are favored as they tend to be a sensitive argument for wealthier households and trigger investment decisions. However, they are very expensive and, as argued by Charlier (2015), they suffer from a misuse in public spending as they carry away detrimental windfall effects.

Energy consumption in private houses stems from three main usages: space heating (61.3% of the total expenditures), hot water and cooking (19.1%), and specific electricity use[2] (19.5%).[3] Moreover, the promotion for energy efficiency in residential buildings is mainly based

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[1] French Ministry of Environment and Energy: http://www.statistiques.developpement-durable.gouv.fr/publications/p/2669/966/chiffres-cles-lenergie-edition-2016.html.
[2] This usage is growing at a very high rate as households and houses are more and more connected, and the appliances evolve toward high technology and multimedia services.
[3] Data are from the Cerema (French center for studies and expertise on risks, environment, mobility and development) for the year 2013 (http://reseaux-chaleur.cerema.fr/consommation-denergie-dans-les-batiments-chiffres-cles-2013).

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on conventional and modeled consumption,[4] which does not thoroughly and narrowly account for household characteristics and effective behaviors—yet, those are necessary in order to offer a comparable set of energy efficiency measures on buildings.

A cross-tabulated analysis enlightens us on the heterogeneity and variability of French households' energy consumption given dwelling types, but also income and energy mix. As shown in Table 1, energy expenditures increase greatly when households live in individual houses rather than in collective dwellings. Indeed, in the case of houses, the level of the annual energy bill is more than doubled, and both the energy budget share and the energy bill weighted per square meter and per inhabitant are increased by respectively 70ct€ and 1.7% compared to collective dwellings. Moreover, energy expenditures and budget shares also vary within each dwelling type according to the energy mix. For example, the energy bill in flats (houses) is 45% (23%) more expensive when households consume a mix of alternative fuels such as butane, domestic fuel, coal or wood rather than an exclusive electric mix—the corresponding budget share being 1.4 pp. (1 pp.) higher. Furthermore, it is also worth noticing that households which use unconventional fuels are between 5% (in houses) and 15% (in flats) poorer than other households on median.

In this paper, our aim is to address specifically the question of heterogeneity in energy residential demand in France, and to identify the factors that explain the gap between expected and realized energy final consumption levels. To this end, we go beyond the average household energy consumption prism as our originality is to rely on a disaggregated-level analysis. In this regard, household group classification can be useful to tackle the rebound effect and the nonlinear demand for energy services.

The "take-back", or "rebound effect",[5] refers to an increase in the supply of energy services, with a corresponding decrease in the effective price, whose size depends upon the underlying cost structure (Greening et al., 2000). When energy efficiency measures do not account for the gap between expected and actual consumptions, they might face some rebound effect. Regarding space heating, that represents about 70% of household energy total expenditures, the estimated rebound effect in the economic literature ranges from 10% to 58% in the short term, and from 1.4% to 60% in the long term (Dubin et al., 1986; Greening et al., 2000; Sorrell and Dimitropoulos, 2008). As shown, the range of the estimated rebound effect values is large, highlighting the importance of having detailed information on household revenue level and repartition decile. Total income defines a budget constraint that drives directly the quantity of energy service consumed and its evolution with price and income dynamics via demand elasticity. Income also influences the implicit discount rate at which households make investment decisions for equipment (Hausman, 1979) or energy efficiency strategies (Hassett and Metcalf, 1993).

The rebound effect can take two forms—direct and indirect.[6] The direct rebound effect refers to the increase in the use of the energy service that experienced a change in price. The indirect rebound effect measures the increase in "sectoral" energy demand driven from the reallocation of energy efficiency savings to other energy consuming goods and services (Khazzoom, 1980). As for some empirical estimates, recent studies have shown that the rebound effect varies depending on whether the substituted service is low-carbon intensive (estimated rebound in the UK of 12%), "behavior as usual" (34% rebound) or carbon intensive. The latter case even produces backfire effect (Druckman, 2011).

In an "ideal situation", the rebound effect is directly estimated from the elasticity of demand for energy services with respect to a change in energy efficiency. However, due to the lack of available accurate corresponding data, the rebound effect is more often measured through the estimate of own-price elasticity of energy service in the empirical literature (Khazzoom, 1980). As argued by Sorrell and Dimitropulos (2008), this method, whether used on cross-sectional or historical variation, can lead to overestimating the rebound. This overestimation is notably due to asymmetry in energy elasticities' estimates and collinearity (Baker and Blundell, 1991). Being aware of these methodological problems, we go further than the previous literature and derive energy consumption from the classification of household groups. Group specification indeed overcomes the nonlinear and collinear relationship between demand and income, and provides a solid outline regarding shifts of the Engel curves[7] according to demographics and household groups.

Disaggregated demand analysis allows us to tackle in a new perspective the issue related to the measures and indicators of fuel poverty in residential housing. In the UK, 80% of the 2,35 million fuel poor are also vulnerable households (Department of Energy and Climate Change; DECC, 2013). The latter can be divided in three categories: low revenue (below 60% of the median income), elderly, allocation benefit households and single parents. Every group has an increased vulnerability to fuel price as corresponding households spend a larger amount of their revenue on energy bills (Hills, 2012). Besides, each group has strong heterogeneous energy consumption habits (Jamasb and Meier, 2011). Housing location is also a major factor that can trigger or identify fuel-poverty through the region's climate and the urban density. The region's climate is playing a key role in the ability to adequately heat a home, along with (i) residing in a rural area followed by (ii) residing in an intermediate area of urbanization (Thomson and Snell, 2013). While, on average, there are similitudes in the fuel poverty rate between rural and urban households, the impact of specific dwelling and socio-demographic aspects combined reveals critical differences. Although urban households are more likely to spend more time in fuel poverty, rural households are expected to fall into worsened levels of fuel poverty (Hills, 2012), and are more vulnerable to fuel prices especially when they live in private rental accommodations (Roberts et al., 2015).

As stressed above, our aim in this paper is to account for heterogeneity in energy consumption by relying on a disaggregated energy consumption analysis of French households. Our contribution to the existing literature is threefold. First, while the bulk of the empirical literature is based on microeconomic tools, such as price elasticity, we rely on a clustering approach—the Chi Square Automatic Interaction Detection (CHAID) approach—allowing us to identify the main drivers of household energy consumption. Second, we propose a detailed typology of households based on a transparent set of characteristics. Third, thanks to our classification, we provide recommendations to improve energy efficiency programs by giving more appropriate and detailed information on the residential housing market than the usual simple average household energy consumption analysis. On

[4] See French Environment and Energy Management Agency.

[5] The rebound effect—also called the "Jevons Paradox"—was highlighted in 1865 by William Stanley Jevons within his famous book, *The Coal Question*. This ecological paradox describes the unexpected consequences in terms of natural resources consumption resulting from a refinement of a technological process. Thereby, the implementation of an improved technology through a more efficient energy process can paradoxically lead to an increase in energy consumption. The widespread use of the technology, the decrease in incentives for the rationalization of energy consumption, the decrease in unit price for energy services and the revenue effect observed through energy efficiency gains can explain the rebound effect (Khazzoom, 1980). This effect has been observed in both the transportation and the residential sectors.

[6] One may add a third form, namely "economy-wide". The "economy-wide" rebound effect captures the structural changes in the economy that come from the new equilibrium between demand and price after an efficiency improvement.

[7] The Engel curve describes how a consumer's behavior in the purchases of a good (food, for instance) changes when said consumer experiences a variation in her/his total resources (income, expenditures). Engel curves may also depend on demographic variables and other consumer characteristics. A good's Engel curve determines its income elasticity, and hence allows us to classify the good as inferior, normal, or luxurious depending on whether the income elasticity is respectively negative, inferior to unity or greater than unity.