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# Household fuel expenditure and residential building energy efficiency ratings in Ireland

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## HIGHLIGHTS

- We model estimate building energy efficiency as function of building characteristics.
- We estimate fuel expenditure as function of energy efficiency and household types.
- Shows how expenditure by fuel type differs with building energy efficiency.
- We report fuel expenditure elasticity of residential building energy efficiency.

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## ABSTRACT

This paper examines the relationship between residential buildings' energy efficiency labels and household energy expenditure, complementing an existing literature comparing theoretical and actual energy use. Residential building energy performance certificates indicate a theoretical energy use based on standardised assumptions about occupancy and energy service demand and are a market signal about the energy performance of a property. This paper quantifies the empirical relationship between households' expenditure on fuel and building energy performance using household expenditure survey data from the Republic of Ireland. The extent of this relationship, i.e. the size of the elasticity parameter, is of direct relevance to policy makers in the context of energy efficiency and climate policy targets. With building energy efficiency measured as a 15-point scale, we find that each rating decline along the scale is associated with a reduction in energy expenditure of 1.6%.



## 1. Introduction

The European Union has set a headline target of a 20% improvement in energy efficiency by 2020 (CEC, 2010; EP and CEC, 2012). Nearly 40% of European final energy consumption occurs in buildings, and specifically within residential buildings, two-thirds of energy use is for space heating (CEC, 2011). Among the policy measures to encourage energy efficiency improvements in residential buildings is an EU framework for energy performance (EP and CEC, 2002), which established a methodological framework for calculating energy performance of buildings. Energy performance certificates (EPC) are now mandatory to complete residential property transactions.

As energy-efficient properties are generally associated with lower running costs and possibly higher levels of comfort, higher energy efficiency is likely to be capitalised in the price or rental rate of a property. Several empirical studies have confirmed such a hypothesis, finding that properties with high EPCs command a price premium. In the Netherlands Brounen and Kok (2011) find a 2.2–10.2% price premium for properties in the top three energy ratings. Cajias and Piazolo (2013) find that a one percent increase in energy efficiency increases the market value of properties by 0.45 percent in Germany. In Ireland Hyland et al. (2013) find that each rating decline along the EPC scale is associated with a 1.3% reduction in price. Property buyers are clearly willing to capitalise the potential energy savings associated with high energy performance buildings, which could be viewed as a policy success of the building energy performance certification process.

But the use of EPCs raises two questions. Are EPCs, which are a theoretical estimate of building energy performance, a good representation of actual energy use within properties? And

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secondly, are EPC ratings a useful proxy for household energy expenditure?

Answers to both questions have relevance for policy practitioners and households. While the first question focuses on potential physical energy savings, the latter focuses on the potential monetary savings. The two questions are not unrelated but there is good reason (discussed later) to assume that a change in an EPC rating will have a different proportional effect on energy use and expenditure.

On the first question there is strong empirical evidence that theoretical energy use systematically differs from actual energy use (e.g. Majcen et al., 2013; Cayre et al., 2011). The deviation between theoretical and actual energy use has implications for policy, as many policy targets are set according to theoretical energy use whereas the potential to achieve such targets depends on actual energy use. Consequently energy savings potential in the residential sector may be misrepresented. This empirical evidence is part of the growing literature on the energy rebound effect across Europe showing that the relationship between EPC ratings and actual energy use is complex and non-linear (Hens et al., 2010, Belgium; Haas and Biermayr, 2000, Austria; Branco et al., 2004, Switzerland).

It is the second question that this paper examines; what is the relationship between EPC ratings and household energy expenditure? The extent of this relationship, i.e. the size of the elasticity parameter, is of relevance to households and policy makers. There is an existing literature that examines residential energy expenditure as a function of household and dwelling characteristics (e.g. Meier and Rehdanz, 2010; Laureti and Secondi, 2012) and also a broader literature, such as Brounen et al. (2012), that also evaluates how thermal characteristics of properties affects energy consumption.

The extension in this paper is to use EPC ratings as measures of building energy performance to explain energy expenditure. EPCs are a Europe-wide measure based on a common methodological framework intended to signal energy use to housing consumers. EPCs are visible to property market participants plus are an official measure of building energy performance. Consequently it is a natural extension to consider the relationship between EPC ratings and household energy expenditure. Such information would be beneficial to property market participants but there is a dearth of research showing the extent to which energy efficiency improvements, as measured by EPCs, lead to lower energy expenditure.

The relationship between EPC ratings and either energy consumption or expenditure will differ, i.e. the magnitude of the elasticities will differ. In the first instance there is empirical evidence of systematic differences between theoretical and actual energy use (e.g. Majcen et al., 2013; Cayre et al., 2011). In addition, because of fixed standing charges on utility bills, tiered pricing (in some instances), as well as the fact that EPC ratings correspond to a fraction of total household energy consumption (i.e. energy for lighting, heating and ventilation but not other uses such as cooking, laundry and entertainment) changes in energy expenditure will not necessarily be proportional to changes in (theoretical) energy consumption.

Knowledge of the relationship between EPC ratings and household energy expenditure serves a number of needs. When evaluating new home choices households will use the elasticity to compare future energy costs across properties. In the context of evaluating investments to improve the energy performance of existing properties (i.e. improving the EPC rating) the elasticity is useful for evaluating the financial return. In the energy policy arena it will contribute to the fuel poverty literature (e.g. Thomson and Snell, 2013), illustrating how families in energy in-efficient homes spend relatively more on energy.

## 2. Theoretical energy use and actual energy expenditure

An EPC is a hypothetical measure of energy efficiency pertaining to energy use for space and water heating, ventilation and lighting within a property. In Ireland it is termed a building energy rating (BER) and expressed in kilowatt-hours per square metre per annum (kW h/m$^2$/yr). Its calculation is based on standardised assumptions relating to occupancy (associated with floor area) and heating patterns (living areas heated to 21 °C and other rooms to 18 °C) (SEAI, 2013).

This engineering calculation by definition will differ from actual energy use for a number of reasons. First, it only covers a portion of household energy use excluding plug loads (e.g. for cooking, laundry, entertainment). Neither households nor utility billing data can easily distinguish energy use for lighting/heating/ventilation purposes verus other energy uses (e.g. a gas utility bill does not distinguish between gas consumed for cooking or heating purposes) hence the focus on total energy expenditure. Second, household preferences will not always match the standardised assumptions. The objective of the paper is to gauge how the theoretical measure of a building's energy efficiency, i.e. its BER rating, relates to the actual energy expenditure of a family resident there. There is no underlying theory for the relationship between BER ratings and energy expenditure but an empirical relationship should exist, a relationship that is likely to be of significant interest to both policy makers as well as households.

In a stylised example of a single composite energy product $E$, energy use within a household comprises energy for heating, lighting and ventilation ($E_{BER}$) as well as energy for other purposes ($E_{OTH}$)

$$E = E_{BER} + E_{OTH} \tag{1}$$

A property's BER rating, $\hat{E}_{BER}$, is an estimate of $E_{BER}$ based on standardised assumptions about household occupancy and preferences for heating and hot water demand. Majcen et al. (2013) and Cayre et al. (2011) have found empirical support for the proposition that theoretical energy use, i.e. BER rating, will not match the actual equivalent energy use; $\hat{E}_{BER} \neq E_{BER}$. If the price of the composite energy product is denoted $P$, the relationship we wish to investigate is:

$$P.E = f\left(\hat{E}_{BER}, \ \ldots\right) \tag{2}$$

Eq. (1) is an equality and its calculation an engineering issue, whereas Eq. (2) also incorporates a behavioural relationship. A household's expenditure will depend on a range of factors such as income, number of family members, preferences in relation to household temperatures, and the utilisation of energy-using devices, in addition to the property's energy efficiency.

The analysis here controls for the behavioural aspects of the relationship, such as household composition, and measures the relationship between BER and energy expenditure. We are not aware of previous studies that have compared household fuel expenditure with EPC ratings. The lack of such studies may reflect the lack of datasets that combine information on households' energy expenditure and energy efficient ratings for their homes.

## 3. Methods

### 3.1. Fuel expenditure equations

Expenditure equations, or Engel curves, are often estimated to investigate how expenditure on a particular good varies with household expenditure or income. Many studies have investigated the best functional specification for Engel curves; Prais and Houthakker (1955) and Leser (1963) are notable examples. The 'Leser-Working' form of Engel curve in which budget shares are regressed on the log of income or expenditure has been widely used in empirical applications. The almost ideal demand system (AIDS) specification of Deaton and Muellbauer (1980) is an example, whereas alternative specifications have also included quadratic or inverse terms for