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# Changes in Household Fuel Expenditure Associated with Improvements in Building Energy Efficiency

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*Abstract*: This paper combines data on residential building energy performance certificates (EPC) and household energy expenditure to estimate expenditure equations (Engel curves) as a function of building energy efficiency and household characteristics. Engle curves for gas, oil, electricity, solid fuel, and aggregate fuel expenditure are estimated for a sample of 5,891 households in the Republic of Ireland. With building energy performance measured using a 7 point letter scale (A to G) our results find that households living in relatively energy inefficient properties spend between €160-€419 per annum more on energy than households in B rated properties. In percentage terms a one letter improvement in building energy rating is associated with a 4-10% change in total household energy expenditure. When energy use for entertainment, cooking, and laundry purposes are excluded, this represents approximately a 6-14% change in energy expenditure for heating, lighting and ventilation purposes (i.e. building related energy).

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# Changes in Household Fuel Expenditure Associated with Improvements in Building Energy Efficiency

## Introduction

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)). With high energy costs one would expect that building energy efficiency is a significant consideration among households and other building users. Prior to 2002 there was no systematic mechanism within Europe to access information on buildings' energy efficiency. Households relied on anecdotal information on energy performance when making decisions on housing and energy use. In 2002 the European Union (EU) passed a directive on energy performance of buildings (EP and CEC (2002)), which aimed to improve awareness of energy consumption and established a methodological framework for calculating energy performance of buildings. Since the implementation of this directive households have had significantly more information about building energy performance, as energy performance certificates, called building energy ratings (BER) in Ireland, are now generally required to complete property transactions. The BER rating is an estimated energy use for space and water heating, ventilation and lighting based on standard occupancy and occupancy behaviour. Properties with better BER ratings will generally tend to have the lowest energy bills, though obviously energy consumption depends on the demand by the property's occupants. Because energy-efficient properties are associated with lower running costs and possibly higher levels of comfort, the value of higher energy efficiency is likely to be capitalised in the price or rental rate of a property. Several empirical studies of residential property prices have confirmed such a hypothesis, finding that properties with high energy rating certification commanding a price premium. Brounen and Kok (2011) find that the top three energy ratings (i.e. A, B and C ratings) command a 2.2-10.2% price premium compared to 'D' rated residential property in The Netherlands. Cajias and Piazolo (2013) find that a one percent increase in energy efficiency increases rents by 0.08 percent and the market value of properties by 0.45 percent in Germany. In Ireland the BER is measured on a 15-point scale and Hyland *et al.* (2013) find that each rating decline along the BER scale is associated with a 1.3% reduction in price. An energy efficiency price premium was also found in the Australian residential property market (Australian Bureau of Statistics (2008)). Price premia for high levels of energy efficiency also exist for commercial property (Kok and Jennen (2012); Eichholtz *et al.* (2010); Reichardt *et al.* (2012)). Property buyers are clearly willing to capitalise the potential energy savings associated with high energy performance buildings in the purchase price. The question that this paper examines is the extent to which higher levels of energy efficiency are actually reflected in lower energy running costs.

This paper empirically tests whether improved building energy performance, as measured by BERs, is associated with the lower levels of domestic energy expenditures in Ireland. While there is a growing literature that shows that higher levels of energy efficiency, as measured by BERs, are being capitalised in property prices there is a dearth of research showing the extent to which energy efficiency, as measured by BERs, leads to lower energy costs. Regulatory authorities responsible for BERs suggest that properties with better BER ratings will generally have the lowest energy bills. But the relationship between a BER ratings and energy expenditure is not straight forward – there isn't a clear tautology between them. A BER is a stylised measure of the energy performance of a home covering energy for lighting, heating and ventilation purposes (incl. associated pumps and fans) whereas household energy expenditure includes energy used in activities that are not included in the BER assessment (e.g. kitchen appliances, laundry, entertainment, etc). Possibly as much as 30% of household primary energy consumption relates to energy use that is not included in the BER assessment (e.g. kitchen appliances, laundry equipment, TVs, etc). For electric energy Dennehy and Howley (2013) estimate that just 42% of electricity use in Irish households is for lighting, heating and ventilation purposes (i.e. included in a BER assessment). For other fuels (i.e. gas, oil, and solid fuels) this proportion is likely to be substantially higher because, with the exception of cooking, these fuels are largely used for space and water heating purposes. Our estimate is that roughly 70% of energy use within Irish households is for purposes that are considered within a BER assessment (e.g. lighting, heating and ventilation including associated pumps and fans).

Nonetheless there is a need to understand to what extent BER, as a measure of building energy efficiency, relates to actual household energy expenditure. Regulatory authorities responsible for BERs suggest that properties with better BER ratings will generally have the lowest energy bills. Households in the property market use BER ratings as a signal for energy costs without necessarily understanding how a BER is calculated. For the average household the subtleties of the BER definition concerning what energy use it includes and excludes, plus the standardised assumptions on occupancy and heating patterns will not be obvious. What is of interest is the extent to which BER can be used to estimate total energy use across property types. That is an empirical issue, which is to determine the extent to which BER ratings are indicative of lower energy costs.

Comparing household energy expenditure with BERs is not straightforward. One issue is that a BER is a hypothetical measure (i.e. based on standardised assumptions) of a portion of total energy used within a property. A BER assessment collects over 120 data measurements pertaining to energy use for space and water heating, ventilation and lighting within a property. With these data and standardised assumptions relating to occupancy (based on floor area) and heating patterns (living areas heated to 21 °C and other rooms to 18 °C) a property's BER assessment is calculated and expressed in kilowatt-hours per square metre per annum(kWh/$m^2$/year) (SEAI (2013)). Actual energy use is likely to differ from that implied by the standardised assumptions. For example, residential room temperatures in Ireland are possibly similar to those in the UK, where average residential internal temperatures are less than 18 °C (Palmer and Cooper (2012)).

In the context of energy efficiency improvements there is a considerable literature on the energy efficiency rebound effect, which refers to behavioural responses that are reflected in increased energy consumption offsetting savings achieved through the introduction of new energy efficient technologies (e.g. Berkhout *et al.* (2000); Herring (2006); Chakravarty *et al.*

(2013); Sorrell *et al.* (2009)). The literature conjectures several reasons for the rebound effect, including that improvements in energy efficiency make energy cheaper and therefore encourage increased consumption. Estimates of the magnitude of the rebound vary by sector and country. For example, in Sweden Nässén and Holmberg (2009) estimate direct rebound effects in heating and transport in the order of 10-20%, whereas Freire González (2010) estimate direct rebound effect of 35% in the short term and 49% in the long term among households in Catalonia. The existence of a rebound effect means that households often offset savings in energy expenditure against improvements in comfort levels. So while fuel expenditure reflects the net effect of a property's energy efficiency including any rebound effect (if there was an improvement in efficiency), the BER rating, as a measure of energy efficiency, reflects the technical energy potential of a property (that is unlikely to be fully realised).

The objective of the paper is to establish the extent to which BER ratings are indicative of lower energy expenditures. Such information has a number of useful purposes. In the property market it represents an explicit quantification of a calculation that households implicitly undertake in evaluating new home choices. It illustrates how families in energy in-efficient homes spend more on energy, which will contribute to the literature measuring and tackling fuel poverty (e.g. Thomson and Snell (2013)). In the context of climate policy it contributes to an understanding of how improvements in energy efficiency are reflected in lower energy use and emissions.

## Methodology

The authors are not aware of previous studies that have compared household fuel expenditure with associated energy efficiency ratings. The lack of such studies may reflect the dearth of datasets that combine information on households' energy expenditure and energy efficient ratings for their homes. This continues to be a problem in the present analysis and although two separate Irish datasets are used, one on residential building BERs and a second on household expenditures, the datasets cannot be directly matched. While the household expenditure dataset provides detailed information on fuel expenditures it contains no information on household energy efficiency, nor can households in the expenditure dataset be directly matched with properties in the BER dataset. Instead we are forced to estimate BER ratings for households in the expenditure dataset.

The basic approach of the paper is to use the BER database to estimate a classification regression for BERs as a function of property characteristics. Using the BER classification regression equation, an estimated BER is calculated for each property in the household expenditure dataset, which is described in the next section. Subsequently the household expenditure dataset is used to estimate fuel expenditure as a function of (estimated) BER rating, family characteristics and other factors likely to affect fuel consumption.

## *Estimating BER Ratings*

The Sustainable Energy Authority of Ireland (SEAI) is the agency responsible for BERs in Ireland and maintains a register of completed BERs.[1] BERs are calculated by a standard assessment procedure, which models energy consumption under standard occupancy and normal climatic conditions, following European standards.[2] A BER does not cover energy used for purposes other than those associated with heating and lighting (e.g. electricity used by kitchen appliances, etc., is not included). In Ireland a BER rating is reported as the total primary energy used and expressed in kilowatt hours per unit area per annum (kWh/$m^2$/year), which is subsequently classified into a 15-point alpha-numeric scale (A1, A2, …, E1, E2, F, G), details of which are in Table 1. A low kWh/$m^2$/year indicates a good energy performance with the alpha-numeric rating beginning with A1 for the most efficient down to G, the lowest energy performance. Actual BER ratings are based on the technical specifications of the property, including heating and ventilation equipment, and are calculated using a bespoke software and procedure.[3] The median property in the BER database has a C3 BER rating, which is between 200-225 kWh/$m^2$/year, though the database is not necessarily representative of the total housing stock. The most frequent BER classifications are between C1 and D2.

We use the BER database, which contains information on household characteristics, to develop a classification regression for BER ratings as a function of key predictor indicators. The key indicators are building age, and type (e.g. apartment), and the fuel used for space and water heating. In the classification regression we confine the explanatory variables to variables that are also contained in the household expenditure dataset, which is used in the next stage of analysis. The regression results are presented in Table 2, where the dependent variable is the logarithm of the BER rating. From this regression we find that recently built properties have progressively better BER ratings. This reflects both improvements in building practice, technologies, and building code regulations over time and mirrors a similar result for property in the UK (DCLG (2010)). An inherent flaw in the model in this case is that the model uses building age and ignores, due to lack of data, whether any refurbishment occurred subsequently. Semi-detached, terrace and detached houses generally have a poorer BER than apartments. The regression uses electricity as the reference fuel for both space and water heating. Properties that use gas or oil as the primary fuel, either for space or water heating, generally have better BER ratings than properties using electricity. We also find that properties that use solid fuel for water heating (e.g. a coal fuelled fireplace with

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1 The database of BERs is available to download at http://www.seai.ie/Your_Building/BER/National_BER_Research_Tool/

2 IS EN 13790: Energy performance of buildings - Calculation of energy use for space heating and cooling

3 Details of the assessment procedure and software are available at http://www.seai.ie/Your_Building/BER/BER_Assessors/Technical/DEAP/

integrated boiler) generally have a better BER rating than properties that primarily use electricity for water heating.

While the model only uses a few explanatory variables, it works reasonably well explaining actual BER ratings with a coefficient of determination, $R^2$, of 0.57. The estimated model, which relies on a relatively small sub-set of the technical data utilised in making an actual BER assessment, explains 57% of the total variation of outcomes. When comparing the actual BER rating with the model predicted BER (both in logarithms), the predicted log BER rating is within 5% of the actual log BER rating for 70% of observations (or within 25% of the BER in kWh/m$^2$/year for 67% of observations). The model is poor at predicting properties with high energy efficiency but across the entire BER dataset just 6% of properties were classified in the top 5 BER categories (A1 to B2). The model is better suited to predicting properties in the bottom ten BER categories. The most frequent BER classifications for Irish residential property are classes C1 to D2, accounting for 62% of properties assessed with a further 24% in classes E1 to G. The regression estimates in Table 2, which are based on the BER dataset, are used to predict a BER classification for each property associated with the households in the household expenditure dataset.

### *Estimating fuel expenditure equations*

Ireland's Central Statistics Office undertakes a Household Budget Survey (HBS) of a representative random sample of all private households in the State with the primary purpose of determining the pattern of household expenditure to update the weighting basis of the Consumer Price Index. During the survey households are required to maintain a detailed diary of household expenditure over a two-week period, including fuel expenditure. Details of bulk fuel purchases during the year outside the two-week diary period are also elicited. The survey was most recently undertaken between August 2009 and September 2010 with 5,891 household participants (CSO (2012)).

Using the HBS dataset we estimate fuel expenditure equations as a function of BER rating and other household characteristics. Expenditure equations, or Engel curves, are often estimated to investigate how expenditure on a particular good varies with household income. Many studies have investigated the best specification for the form of the 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 (1980b) is an example, whereas alternative specifications have also included quadratic or inverse terms for expenditure or income, such as in Pollak and Wales (1980). Using earlier HBS survey data for Ireland both Leser (1964) and more recently Conniffe (2000a) estimated Engel functions, with actual expenditure on fuel $i$ rather than fuel share as the dependent variable as a function of income, $Y$.

$$\boldsymbol{e_i = \alpha_i + \beta_i ln(Y)} \qquad (1)$$

To incorporate household characteristics $(\mathrm{H})$ and the effect of properties' BER on fuel expenditure we assume that they have an impact on the constant term, such that

$$\boldsymbol{e_i} = \boldsymbol{\alpha}_i + \boldsymbol{\gamma}_i \,\mathbf{ln(BER)} + \boldsymbol{\varphi}_i \mathbf{H} + \boldsymbol{\beta}_i \boldsymbol{ln(Y)} \tag{2}$$

From this we can derive two elasticities of interest. The fuel expenditure elasticity of income, $\xi_{e_i\mathrm{Y}}$, is the percentage change in expenditure on fuel $i$ for a percentage change in income. The fuel expenditure elasticity of BER rating, $\xi_{e_i\mathrm{BER}}$, is the percentage change in expenditure on fuel $i$ for a percentage change in BER value.

$$\boldsymbol{\xi_{e_i\mathrm{Y}}} = \frac{\boldsymbol{\beta_i}}{\boldsymbol{e_i}} \tag{3}$$

$$\boldsymbol{\xi_{e_i\mathrm{BER}}} = \frac{\boldsymbol{\gamma_i}}{\boldsymbol{e_i}} \tag{4}$$

Estimating (2) for total fuel expenditure is straightforward and from a policy perspective potentially of most interest for investigating whether relating to household fuel poverty or energy efficiency. Estimation of fuel specific expenditure equations is slightly more complex. With the exception of electricity, all households do not purchase each fuel type. In the case of gas, oil and solid fuels there are numerous observations with zero expenditure. Data censoring of this nature is a frequently encountered problem in applied demand analysis (e.g. Long (1997); Deaton and Muellbauer (1980a) Yen and Lin (2006)) and disregarding censoring produces biased estimates. Tobin (1958) was the first to address the issue and develop a modified approach to analysing consumer demand. Numerous models have subsequently been developed to address the censoring issue, including the Heckman selection model (Heckman (1979); Heckman (1976); Lewis (1976); Gronau (1974)). The Heckman approach is formulated as a two equation model, a detailed explanation of which can be found in Greene (2002). The first equation determines selection into the sample, in this case it is the qualitative decision whether to purchase a fuel or not, and takes the following form:

$$\mathbf{z}_i^* = \boldsymbol{\delta}_i \mathbf{D} + \boldsymbol{\nu} \tag{5}$$

The second equation describes the quantitative decision, in this case how much fuel to purchase

$$\boldsymbol{e_i} = \boldsymbol{\alpha}_i + \boldsymbol{\gamma}_i \,\mathbf{ln(BER)} + \boldsymbol{\varphi}_i \mathbf{H} + \boldsymbol{\beta}_i \boldsymbol{ln(Y)} + \boldsymbol{\varepsilon} = \boldsymbol{\Phi}_i \mathbf{X} + \boldsymbol{\varepsilon} \tag{6}$$

Where $e_i$ is observed if $z_i^*$ is greater than zero, i.e.:

$$\boldsymbol{e_i} = \begin{cases} \boldsymbol{\Phi}_i \mathbf{X} + \boldsymbol{\varepsilon} & \boldsymbol{if\ z_i^* > 0} \\ - & \boldsymbol{if\ z_i^* = 0} \end{cases} \tag{7}$$

The error terms, $\nu$ and ε are assumed bivariate normal with correlation coefficient $\rho$:

$$\boldsymbol{\nu} \sim \boldsymbol{N(0, \sigma)}$$

$$\boldsymbol{\varepsilon} \sim \boldsymbol{N(0, 1)}$$

$$\boldsymbol{corr}(\mathbf{\nu}, \boldsymbol{\varepsilon}) = \boldsymbol{\rho}$$

We suspect that the error terms are correlated (i.e. that $\rho \neq 0$). For instance, how much fuel a household purchases depends on whether such a fuel is either available to or convenient for a particular household. Mains gas connection is limited to the major urban areas where the gas network exists. Bottled gas or other fuels are widely available but a household's energy infrastructure (i.e. whether it can accommodate every available fuel) or the type of energy using equipment within a household will affect which fuels a household will seek to purchase. Consequently we estimate using the Heckman procedure.

We model the decision to purchase a fuel as a function of household characteristics. It is not unreasonable to assume that properties built in certain locations, during certain periods or properties of specific types may be more likely to use one fuel over another: e.g. oil in rural areas, gas in urban areas, or electricity in apartments. While the decision on whether to purchase a fuel may also be a function of the availability of the fuel locally, the HBS dataset does not contain information of this nature so cannot be incorporated into the estimated selection equation.

## Data

The HBS dataset contains expenditure on four classes of fuels: electricity, gas, solid fuel (e.g. coal), and liquid fuels (e.g. oil). Descriptive statistics for these and other variables used in the estimation are contained in Table 3. As a social welfare measure certain qualifying households, mostly people aged 65 and above, receive directly on their electricity or gas bill an exemption from a meter standing charge and an allowance of free electricity or gas. In 2009/10 16% of households possessed the free electricity allowance and a further 5% of households possessed the free gas allowance. The value of either allowance was equivalent to €10.09/week during the survey period. These allowances represent both implicit income and expenditure. Conniffe (2000b) discusses how the electricity allowance affects income elasticity estimates makes a case that prior to estimating the Engel function that the value of implicit fuel associated with these schemes should be added to allowance holders' recorded fuel expenditures and the same sum added to household income. We follow the same approach here for estimation. There are also other social welfare allowances schemes eligible to low income households but being cash payments and spent like any other income, do not distort measures of fuel expenditures. However, in the analysis we control for 'medical card' recipient households, which is a means-tested entitlement to health care and other supports that may affect fuel expenditures compared to non-medical card recipients.

Though Engle curves for energy expenditure are often estimated without reference to property types (Conniffe (2000a); Leser (1964); Pratschke (1969)) our hypothesis is that the level of energy expenditure is affected by property characteristics. We assume that the entire effect of property characteristics on energy expenditure is captured through the BER variable. Consequently, we only include the BER variable (estimated for each household in the HBS) in the estimated Engle equation plus other variables on household characteristics (e.g. family composition). However, using estimates of households' BER values as an explanatory variable in the expenditure equation potentially biases coefficient estimates. We investigate this issue using bootstrap techniques.

## Results

The gas, oil and solid fuel expenditure equations were estimated with the 'heckman' routine within Stata, which jointly estimates the selection and expenditure equations by maximum likelihood. The results for the selection equations are reported in Table 4. The $\chi^2$ statistic reported for each equation is a likelihood ratio test equivalent to $\rho = 0$, that the Heckman selection equation is appropriate.

The variables that are statistically important in the selection equations vary by fuel but access or connectivity to fuel appears to be important. Mains gas connectivity is an important factor in explaining the decision to purchase gas, though there is always the option of bottled gas. Both the region and locality variables possibly capture some element of fuel availability in terms of access to the gas network or the conventional fuel choice in certain localities. Building type is also important because building types preclude certain fuel choices. For example, many apartments were built when gas supply was not permitted by building regulations nor is oil storage convenient so these fuels are significantly less likely to be purchased by apartment dwellers.

The Engel equation estimates are presented in Table 5. The gas, oil and solid fuel equations are estimated by the Heckman procedure, equation (7), whereas the electricity and total fuel expenditure equations are estimated by OLS. As might be anticipated fuel expenditure is affected by household composition. In general, households with children spend more on fuels than the reference category of a single working-aged adult. This is reflects the fact that proportionately more families compared to single adults live in larger properties that generally require more heating and with more people require more hot water. In the case of solid fuel we find no discernible affect of family composition on expenditure.

The 'medical card holders' variable is a dummy for households that are recipients of a means-tested health care support that is used as a proxy for other social welfare supports, including a fuel allowance. The parameter estimates suggest that such households spend more on fuel, except oil, compared to non-medical card recipients.

The level of income is significant in explaining the level of fuel expenditure, except for solid fuel. The elasticity estimates are reported in Table 6 along with elasticity estimates from previously published studies of earlier Household Budget Surveys dating from 1951-52. What is notable from the table is that estimates of fuel income elasticities have declined substantially over time. This result reflects the growth in general standard of living over the past half century in Ireland. The elasticity for electricity has fallen from 1.01 in 1951-52 to the latest estimate of 0.05, with the most dramatic fall over the past decade. These relatively low income elasticity estimates are comparable with estimates for other countries. Jamasb and Meier (2010) estimate income elasticities in Great Britain for electricity, gas, and all energy at 0.06. Using a different modelling approach on the same data Meier *et al.* (2012) estimate income elasticities of 0.18 for electricity, 0.14 for gas and 0.15 for all energy.

Whereas Nesbakken (1999) estimates income elasticities between 0.18-0.22 for energy among Norwegian households.

The primary focus of this paper is the coefficient estimate on the BER variable. Across all fuels the coefficient is statistically significant. Improved energy efficiency, as calculated by BER ratings, is associated with lower levels of household energy expenditure. The BER ratings are measures of kWh/m$^2$/year so a positive sign was expected; higher BER ratings are associated with higher levels of fuel expenditure. The BER elasticities of fuel expenditure, calculated at mean fuel expenditure per equation (6), are reported in Table 7. The elasticity estimates are relatively low in magnitude ranging from 0.18 to 0.32 for gas, oil and electricity but substantially higher at 1.08 for solid fuels. The BER elasticity estimate for all fuel expenditure is estimated at 0.12. We had no clear a priori on the size of these elasticities, nor are aware of comparative estimates elsewhere.

Assuming a single BER elasticity value for all types of properties and in particular for properties across the BER spectrum is restrictive and probably unrealistic. One might expect that the proportionate change in energy expenditure associated with a change in energy efficiency would be greater in properties with poor energy efficiency. We re-estimated the models using a discrete BER variable based on the 7 letter categories in the BER. The estimates for the total energy expenditure equation are presented in Table 8. The re-estimated fuel specific equations are not reported as the individual coefficient estimates on the discrete BER variables were generally not statistically significant. The BER reference category used in the regression is a B BER rating so the coefficients are interpreted relative to energy expenditure in B rated properties. All coefficients are positive so properties with poorer energy efficiency ratings spend more on energy, controlling for other factors. Properties with an E rating spend on average €4.45 per week more on energy than B rated properties, whereas households in F rated properties spend €7.98 more per week. At a 5% significance level the C and G coefficients are insignificantly different than B rated properties. Given that B and C ratings are adjacent we would expect that difference in energy expenditure to be lowest across BER categories. But finding the coefficient for the most energy inefficient properties, i.e. G rated, to be insignificant (and the magnitude of the coefficient to be relatively low) was unexpected and is difficult to explain. Properties with G ratings are a disparate group and have a disproportionate representation of low income households, and households in the “other household composition” category that was described in Table 3.

With a categorical variable we calculate the BER elasticities as the differences in expenditure between BER ratings divided by the average energy expenditure of households living in properties with the base BER rating. The calculations are reported in Table 9. Because we are using discrete BER variables we have two elasticity values associated with each BER rating. For example, a move from an E to a D rated property is associated with a 4% reduction in fuel expenditure, whereas a move from an E to an F rated property is associated with a 10% increase in fuel expenditure. Because of the relative magnitudes of the coefficients on F and G rated variables the sign on the associated elasticities is the opposite of what might be anticipated and while the estimates are statistically significant are difficult to rationalise. The estimates for the G rated properties aside, these estimates suggest that a one letter change in BER rating is associated with expenditure changes of 4-10%.

As noted earlier the inclusion of an estimated BER value as an explanatory variable may potentially lead to bias in coefficient estimates. To address this issue the “all fuel” expenditure equation was re-estimated (both the continuous and discrete BER variable cases) using a bootstrap technique. Using the mean and variance-covariance estimates associated with the classification regression (Table 2), which was used to estimate a BER rating for households in the HBS survey, and assuming a normal distribution 100,000 draws of the parameter vector were generated. For each draw an estimated BER rating was calculated for each of the 5,812 households in the HBS dataset and an expenditure equation for total fuel expenditure was re-estimated. The bootstrap estimates are also presented in Table 8, where we find that there is no substantial difference in the coefficients compared to the original OLS estimates. Households in D rated properties spend €3.07 per week more on energy; €4.30 in E rated properties; €8.07 in F rated properties compared to B rated properties. The parameter estimate on G rated properties is not statistically significant (i.e. not different than B rated properties). Over the course of a year households in D, E and F rated properties spend €160, €224 and €419 more on energy per annum than households in B rated properties.

Table 10 reports the associated BER elasticities, including 90% confidence intervals, from the bootstrap estimation. Only elasticities that are significantly different than zero are reported in Table 10, and are consistent with the earlier reported elasticities. There is roughly a 6% difference in energy expenditure associated with C and D rated properties; a 4% difference associated with D and E properties; and a 10% difference associated with E and F properties.

The BER elasticity associated with a continuous BER rating variable calculated from the bootstrap analysis is 0.121 with a 90% confidence interval of (0.120, 0.122). This is a point elasticity estimate and is comparable in magnitude to the previous estimate. As noted earlier it is somewhat unrealistic to expect a constant elasticity value across properties with substantially different levels of energy efficiency.

These elasticity estimates are not measures of cause and effect for a number of reasons. The expenditure dataset is a cross-section panel and while households will differ across the panel, the data is not measuring a response to a change in building energy efficiency. Second, there may be other unobserved factors correlated with a property’s BER rating that affect energy consumption, for example, daytime occupancy rates and associated space heating requirements.

A 4-10% reduction in energy expenditure associated with a one letter improvement along the BER scale (excluding A, B and G rated properties) is relatively low but the expenditure measure includes energy both for lighting, heating and ventilation (i.e. included in the BER assessment) and for other uses (i.e. excluded from BER assessment). As discussed earlier, our estimate is that roughly 70% of energy use within Irish households is for purposes that are considered within BER assessments (e.g. lighting, heating and ventilation (incl. associated pumps and fans). Adjusting for energy used for ‘non-BER’ purposes, we could infer that a one letter improvement along the BER scale (e.g. D to C) is associated with approximately a 6-14% reduction in energy expenditure for lighting, heating and ventilation purposes.

Improvements in energy efficiency are also widely coupled with rebound effects, where the energy efficiency improvements are offset by increased energy consumption. There is considerable debate in the literature on the magnitude of the rebound with estimates varying by sector and region. In a review of some 500 rebound studies Sorrell (2007) concludes that the direct rebound effect for household heating is likely to be less than 30%. On that basis a one letter change in BER value (e.g. D to C) might be associated with a potential 8.5-20% reduction in energy expenditure for lighting, heating and ventilation purposes assuming no change in behaviour or rebound effect.

The authors were unable to find a directly comparable analysis in the literature but it is interesting to compare with a study by Scheer *et al.* (2013), which examines the direct effect on energy consumption due to investment in energy efficiency investments in a sample of 210 Irish households.  Their analysis finds that investments in energy efficiency retro-fits achieved a 17–24% reduction in energy use. Their analysis focuses on energy use rather than expenditure. The proportionate change in energy use is necessarily greater than energy expenditure due to the fixed tariff element of utility bills but even allowing for this it is likely that elasticity estimates here are likely to be lower than the unknown expenditure reductions in *Scheer et al's* study. However, it should be noted that the Scheer *et al.* analysis specifically examined energy savings associated with property retrofits using *ex ante* and *ex post* data (from a sample that is potentially prone to selection bias), whereas the analysis here is based on cross-section panel data that did not measure household responses to changes in building energy efficiency.

Hyland *et al.* (2013) examine the effect of Irish BER ratings on house prices and rental rates. When prices were analysed by BER letter scale the rental premium for a one letter change in BER rating (e.g. C to D or vice versa) ranged between 1.3-4.5%, whereas in property sales the price premium varied between 1.7-11%. Property buyers and renters recognise the value of better BER ratings (presumably capitalising the value of energy expenditure savings in higher rental or sales prices). It is not possible to directly compare the results of both analyses the magnitude of these price premiums is not inconsistent with the BER elasticity estimates above.

## Conclusions

Building energy rating certificates are intended to allow property buyers and tenants take energy performance into consideration in their decision to purchase or rent a home. There is clear evidence in Ireland and elsewhere that households are willing to pay a price premium for energy efficiency (Hyland *et al.* (2013); Brounen and Kok (2011); Cajias and Piazolo (2013)). One would also expect that properties with higher levels of energy efficiency to have proportionately lower energy running costs. But we cannot assume that the actual energy demand of property occupants will match the BER rating, as energy use is likely to be neither standard nor uniform, as assumed in the BER assessment process. To understand the relationship between BER and energy expenditure we must analyse energy expenditure data. Investigating the relationship between building energy costs and energy efficiency ratings is difficult, as information about building energy performance, energy consumption and household occupancy are not usually recorded together or easily matched. The approach here uses the BER dataset to model BER ratings as a function of household characteristics, which is then analysed in the context of household occupancy and energy consumption.

The analysis finds statistical support for the assertion that improvements in energy efficiency, as calculated by BER ratings, is associated with reductions in household energy expenditure. For all energy expenditure the point estimate of the BER elasticity is 0.12 but we find that the elasticity varies depending on the energy efficiency of properties. We find that a one letter change in BER rating between C and F ratings is associated with a 4-10% change in total energy expenditure, or approximately 6-14% change in energy expenditure for heating, lighting and ventilation purposes (i.e. BER-related energy). Over the course of a year households in D, E and F rated properties spend €160, €224 and €419 more on energy per annum than households in B rated properties. For the most energy efficient properties we did not detect a statistically significant change in energy expenditure associated with a one letter change in BER rating (e.g. from a C to B rated property). For the least energy efficient properties (i.e. G rated) we found results contrary to expectations: an improvement in energy efficiency is associated with higher energy expenditure. This result is most likely a reflection of the data employed rather than a representation of reality. The data used is a cross-section household panel and captures variation across households rather than within household responses to changes in building energy efficiency. A second issue is that in the dataset the most and least energy efficient properties represent just 7% and 8% respectively of the observations in the dataset and the result may be driven by sample size.

The paper provides useful information for policy practitioners. It presents an initial estimate of how improvements in building energy efficiency are reflected in lower household energy bills. The Irish government is committed to the implementation of *Better Energy: the National Upgrade Programme*, which aims to support the energy efficiency upgrades of one million homes, businesses and public buildings. This paper's estimates, in particular the elasticity estimates, enable better estimation of the magnitude of the potential energy cost savings associated with investment in retro-fitting buildings. At individual fuel level the information will inform decisions on energy supply needs in light of policy efforts to improve the energy performance of buildings and the EU's target of a 20 per cent improvement in energy efficiency by 2020. The Irish government is also committed to the implementation of *Warmer Homes: A Strategy for Affordable Energy in Ireland*, which aims to ensure that households can achieve affordable access to their energy requirements and protect those at risk of energy poverty. While not considered in this paper, income and energy poverty are closely aligned, and low income households oftentimes live in the least energy efficient properties. The paper demonstrates how improving building energy efficiency can have a direct impact on the expenditure choices of low income households.

**Table 1: BER classification for residential buildings in Ireland**

| Rating | kWh/m2/yr | Frequency | % |
|---|---|---|---|
| A1 | <= 25 | 9 | 0.0 |
| A2 | > 25 | 87 | 0.0 |
| A3 | > 50 | 1,755 | 0.5 |
| B1 | > 75 | 6,230 | 1.7 |
| B2 | > 100 | 14,103 | 3.9 |
| B3 | > 125 | 29,255 | 8.1 |
| C1 | > 150 | 40,037 | 11.0 |
| C2 | > 175 | 45,174 | 12.4 |
| C3 | > 200 | 47,157 | 13.0 |
| D1 | > 225 | 48,012 | 13.2 |
| D2 | > 260 | 42,999 | 11.8 |
| E1 | > 300 | 24,493 | 6.7 |
| E2 | > 340 | 19,219 | 5.3 |
| F | > 380 | 18,996 | 5.2 |
| G | > 450 | 25,963 | 7.1 |

Source: SEAI, April 2013

**Table 2: Classification regression for BER for residential buildings**

| Dependent variable Log(BER) | |
|---|---|
| **Year Built** | |
| Pre 1918 | Ref |
| 1918-1945 | -0.079***(0.004) |
| 1946-1960 | -0.122***(0.004) |
| 1961-1970 | -0.233***(0.004) |
| 1971-1980 | -0.314***(0.003) |
| 1981-1990 | -0.405***(0.003) |
| 1991-2000 | -0.497***(0.003) |
| 2001-2005 | -0.610***(0.003) |
| 2006- | -0.854***(0.003) |
| **Property type** | |
| Apartment | Ref |
| Semi-detached/terrace House | 0.055***(0.002) |
| Detached house | 0.056***(0.002) |
| **Primary space heating fuel** | |
| Electricity | Ref |
| Gas | -0.229***(0.010) |
| Solid fuel | 0.287***(0.009) |
| Oil | -0.202***(0.010) |
| **Primary water heating fuel** | |
| Electricity | Ref |
| Gas | -0.289***(0.010) |
| Solid fuel | -0.348***(0.009) |
| Oil | -0.305***(0.010) |
| | |
| Immersion In Summer | 0.143***(0.001) |
| Constant | 6.248***(0.003) |
| | |
| Observations | 358,676 |
| R-squared | 0.571 |

Ref refers to reference category used.
Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

### Table 3: Descriptive Statistics, Household Budget Survey

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| Electricity expenditure (€/week) | 5872 | 17.44 | 10.25 | 0 | 126.98 |
| Gas expenditure(€/week) | 5872 | 8.62 | 14.39 | 0 | 304.70 |
| Oil expenditure (€/week) | 5872 | 6.92 | 11.01 | 0 | 162.25 |
| Solid fuel expenditure (€/week) | 5872 | 3.21 | 13.91 | 0 | 750.00 |
| Total energy expenditure (€/week) | 5872 | 36.19 | 23.61 | 1.91 | 765.10 |
| BER - $kWh/m^2$/year | 5872 | 265.99 | 103.14 | 97.73 | 840.06 |
| Log (BER) | 5872 | 5.52 | 0.35 | 4.58 | 6.73 |
| Medical card holders | 5872 | 0.39 | 0.49 | 0 | 1 |
| Single working-aged adults | 5872 | 0.15 | 0.36 | 0 | 1 |
| Single retired-aged adults | 5872 | 0.07 | 0.26 | 0 | 1 |
| Couple | 5872 | 0.17 | 0.37 | 0 | 1 |
| Couple 1 child | 5872 | 0.07 | 0.25 | 0 | 1 |
| Couple 2 children | 5872 | 0.09 | 0.28 | 0 | 1 |
| Couple 3 or more children | 5872 | 0.07 | 0.26 | 0 | 1 |
| Single adult | 5872 | 0.07 | 0.26 | 0 | 1 |
| Other household composition | 5872 | 0.30 | 0.46 | 0 | 1 |
| Disposable income (€/week) | 5872 | 905.37 | 671.30 | 0.38 | 12341.93 |
| Log disposable income (€/week) | 5872 | 6.57 | 0.73 | -0.97 | 9.42 |
| **Urban/Rural** | | | | | |
| County bourghs & suburbs | 5872 | 0.39 | 0.49 | 0 | 1 |
| Towns | 5872 | 0.29 | 0.45 | 0 | 1 |
| Mixed urban/rural area | 5872 | 0.19 | 0.39 | 0 | 1 |
| Rural | 5872 | 0.12 | 0.33 | 0 | 1 |
| **Gas/Electricity connection** | | | | | |
| Electricity only | 5872 | 0.57 | 0.50 | 0 | 1 |
| Both Electricity and gas | 5872 | 0.43 | 0.50 | 0 | 1 |
| **Year property built** | | | | | |
| pre 1945 | 5872 | 0.17 | 0.37 | 0 | 1 |
| 1946-1980 | 5872 | 0.26 | 0.44 | 0 | 1 |
| 1981-2005 | 5872 | 0.44 | 0.50 | 0 | 1 |
| 2006- | 5872 | 0.13 | 0.34 | 0 | 1 |
| **Region** | | | | | |
| Border, Midland and West | 5872 | 0.27 | 0.44 | 0 | 1 |
| South | 5872 | 0.43 | 0.49 | 0 | 1 |
| Dublin | 5872 | 0.31 | 0.46 | 0 | 1 |
| **Property type** | | | | | |
| Apartment | 5872 | 0.14 | 0.35 | 0 | 1 |
| Semi-detached /terrace house | 5872 | 0.52 | 0.50 | 0 | 1 |
| House | 5872 | 0.34 | 0.47 | 0 | 1 |

### Table 4: Heckman selection equation estimates

| | Gas | Oil | Solid Fuel |
|---|---|---|---|
| **Locality type** | | | |
| Towns | 0.147 | 0.214*** | 0.193*** |
| | (0.141) | (0.074) | (0.063) |
| Mixed urban/rural area | 0.154 | 0.297*** | 0.341*** |
| | (0.150) | (0.080) | (0.070) |
| Rural | 0.181 | 0.164* | 0.408*** |
| | (0.162) | (0.090) | (0.079) |
| County boroughs | Ref | Ref | Ref |
| **Gas supply** | | | |
| Gas supply at property | 4.777*** | -1.842*** | -0.359*** |
| | (0.159) | (0.058) | (0.049) |
| **Year built** | | | |
| Pre 1946 | Ref | Ref | Ref |
| 1946-1980 | -0.157 | 0.271*** | -0.092 |
| | (0.115) | (0.070) | (0.058) |
| 1981-2005 | -0.130 | 0.055 | -0.196*** |
| | (0.103) | (0.064) | (0.054) |
| 2006- | -0.323** | 0.147* | -0.258*** |
| | (0.146) | (0.084) | (0.072) |
| **Region** | | | |
| Border, Midlands, West | Ref | Ref | Ref |
| South | -0.176** | -0.149*** | 0.049 |
| | (0.080) | (0.050) | (0.046) |
| Dublin | -0.165 | -0.489*** | -0.110 |
| | (0.167) | (0.091) | (0.076) |
| **Building type** | | | |
| Detached house | Ref | Ref | Ref |
| apartment | -0.314** | -2.585*** | -1.102*** |
| | (0.148) | (0.127) | (0.093) |
| Semi-detached/terrace house | -0.118 | -0.657*** | -0.153*** |
| | (0.089) | (0.051) | (0.045) |
| Constant | -1.531*** | 0.800*** | -0.431*** |
| | (0.176) | (0.100) | (0.085) |
| $\rho$ | -0.105*** | -0.183*** | -0.145*** |
| | (0.037) | (0.042) | (0.055) |
| $\chi^2$ | 7.21 | 15.75 | 5.85 |

Standard are errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

**Table 5: Fuel expenditure equation regressions**

| Dependent variable: Weekly fuel expenditure | Gas | Oil | Electricity | Solid Fuel | All Fuels |
|---|---|---|---|---|---|
| Log(BER) | 2.314** | 2.214*** | 3.204*** | 3.480* | 4.363*** |
| | (1.001) | (0.807) | (0.411) | (1.955) | (1.025) |
| Medical card holders | 2.769*** | -1.724*** | 0.412 | 3.666** | 2.325*** |
| | (0.757) | (0.516) | (0.322) | (1.678) | (0.705) |
| **Household Composition** | | | | | |
| (Reference category, Single working-aged adults) | | | | | |
| Single retired-aged adults | -0.756 | 1.942* | 0.415 | -2.003 | -0.190 |
| | (1.493) | (1.070) | (0.482) | (3.442) | (1.353) |
| Couple | 1.483 | 2.804*** | 3.598*** | -1.929 | 5.344*** |
| | (1.104) | (0.868) | (0.382) | (2.659) | (1.356) |
| Couple with 1 child | 2.745* | 0.416 | 5.963*** | -3.910 | 6.654*** |
| | (1.415) | (1.113) | (0.554) | (3.393) | (1.414) |
| Couple with 2 children | 5.776*** | 2.544** | 8.652*** | -2.662 | 11.306*** |
| | (1.271) | (1.024) | (0.598) | (3.278) | (1.507) |
| Couple with 3+ children | 5.443*** | 3.219*** | 10.383*** | -4.161 | 12.227*** |
| | (1.435) | (1.046) | (0.630) | (3.337) | (1.626) |
| Single parent | 4.986*** | -0.488 | 4.947*** | -2.949 | 7.073*** |
| | (1.347) | (1.166) | (0.596) | (3.358) | (1.318) |
| Other household composition | 4.210*** | 0.347 | 6.254*** | -2.462 | 7.601*** |
| | (0.979) | (0.876) | (0.382) | (2.629) | (1.259) |
| **Income** | | | | | |
| Log(disposable income) | 0.864* | 2.637*** | 0.838*** | 0.806 | 2.842*** |
| | (0.518) | (0.405) | (0.249) | (1.329) | (0.484) |
| **Date Surveyed** | | | | | |
| Quarter 4 2009 | -0.616 | 0.389 | 0.713 | -3.929 | 0.644 |
| | (1.107) | (0.873) | (0.442) | (2.634) | (1.610) |
| Quarter 1 2010 | 9.110*** | 2.447*** | 2.438*** | -3.702 | 8.378*** |
| | (1.063) | (0.842) | (0.454) | (2.570) | (1.569) |
| Quarter 2 2010 | 8.705*** | 4.141*** | 2.572*** | -7.870*** | 6.575*** |
| | (1.077) | (0.863) | (0.465) | (2.771) | (1.559) |
| Quarter 3 2010 | -0.100 | 4.303*** | 0.832* | -7.734** | 0.153 |
| | (1.114) | (0.950) | (0.472) | (3.091) | (1.585) |
| Constant | -10.837* | -14.267*** | -12.311*** | -1.811 | -33.981*** |
| | (6.410) | (5.375) | (3.007) | (14.631) | (6.873) |
| **Property type** | | | | | |
| (Reference category, apartment) | | | | | |
| House | 5.205*** | | | | 16.488*** |
| | (1.096) | | | | (1.084) |
| Semi-detached/terrace house | 3.532*** | | | | 6.837*** |
| | (0.882) | | | | (0.832) |
| **Central Heating** | | | | | |
| Gas | | | | | 9.573*** |
| Oil | | | | | 8.373*** |
| Electric | | | | | 0.707 |
| Solid fuel | | | | | 3.363*** |

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

**Table 6: Income elasticity estimates, including estimates from previous Household Budget Surveys**

| HBS | 1951-52 | 1965-66 | 1973 | 1980 | 1987 | 1994-95 | 2004-05 | 2009-10 |
|---|---|---|---|---|---|---|---|---|
| Total fuels | 0.5 | 0.32 | 0.46 | 0.48 | 0.43 | 0.25 | 0.22 | 0.08*** |
| Gas | 0.48 | 0.47 | 0.2 | 0.44 | 0.37 | 0.75 | 0.39 | 0.10* |
| Electricity | 1.01 | 0.82 | 0.87 | 0.72 | 0.76 | 0.35 | 0.35 | 0.05*** |
| Coal | 0.59 | 0.08 ns | 0.06 ns | 0.02 ns | -0.01 ns | -0.29 ns | -0.33 | 0.25ns[a] |
| Turf | na | 0.51 | -0.69 | -0.55 | -0.5 | -0.3 | na | na |
| Oil | na | na | na | 1.54 | 1.85 | 0.96 | 0.27 | 0.38*** |

*Source*: Leser (1964); Pratschke (1969); Murphy (1976); Conniffe and Scott (1990); Conniffe (2000a); Scott *et al.* (2008). na: no estimate available. ns: estimate not statistically significant. [a] The estimate for 2009-10 relates to solid fuels and not specifically coal. *** p<0.01, ** p<0.05, * p<0.1.

**Table 7: BER elasticities of fuel expenditure**

| | Gas | Oil | Electricity | Solid Fuel | All fuels |
|---|---|---|---|---|---|
| BER elasticity | 0.27** | 0.32*** | 0.18*** | 1.08* | 0.12*** |
| | (0.12) | (0.12) | (0.02) | (0.61) | (0.03) |

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

**Table 8: Fuel expenditure equation regressions**

| Dependent variable: Weekly fuel expenditure | All Fuels OLS | All Fuels Bootstrap | All Fuels OLS | All Fuels Bootstrap |
|---|---|---|---|---|
| **BER rating** | | | | |
| Log(BER) | | | 4.363*** | 4.362*** |
| | | | (1.013) | (1.013) |
| (Reference category – 'B' rating) | | | | |
| 'C' BER | 0.800 | 0.809 | | |
| | (1.169) | (1.168) | | |
| 'D' BER | 3.001** | 3.070*** | | |
| | (1.187) | (1.182) | | |
| 'E' BER | 4.454*** | 4.302*** | | |
| | (1.250) | (1.263) | | |
| 'F' BER | 7.980*** | 8.050** | | |
| | (2.030) | (1.946) | | |
| 'G'BER | 1.659 | 1.663 | | |
| | (1.898) | (1.893) | | |
| | | | | |
| Medical card holders | 2.407*** | 2.409*** | 2.325*** | 2.325*** |
| | | | | |
| **Household Composition** | | | | |
| (Reference category, Single working-aged adults) | | | | |
| Single retired-aged adults | -0.238 | -0.225 | -0.190 | -0.190 |
| Couple | 5.235*** | 5.231*** | 5.344*** | 5.345*** |
| Couple with 1 child | 6.627*** | 6.637*** | 6.654*** | 6.654*** |
| Couple with 2 children | 11.261*** | 11.255*** | 11.306*** | 11.306*** |
| Couple with 3+ children | 12.143*** | 12.134*** | 12.227*** | 12.227*** |
| Single parent | 6.931*** | 6.925*** | 7.073*** | 7.073*** |
| Other household composition | 7.515*** | 7.507*** | 7.601*** | 7.601*** |
| **Income** | | | | |
| Log(disposable income) | 2.835*** | 2.846*** | 2.842*** | 2.842*** |
| **Date Surveyed** | | | | |
| Quarter 4 2009 | 0.710 | 0.709 | 0.644 | 0.644 |
| Quarter 1 2010 | 8.460*** | 8.464*** | 8.378*** | 8.378*** |
| Quarter 2 2010 | 6.497*** | 6.504*** | 6.575*** | 6.575*** |
| Quarter 3 2010 | 0.165 | 0.166 | 0.153 | 0.153 |
| Constant | -11.114*** | -11.163*** | -33.981*** | -33.977*** |
| | | | | |
| **Property type** | | | | |
| (Reference category, apartment) | | | | |
| House | 16.769*** | 16.741*** | 16.488*** | 16.488*** |
| Semi-detached/terrace house | 7.051*** | 7.055*** | 6.837*** | 6.837*** |
| **Central Heating** | | | | |
| Gas | 7.865*** | 7.854*** | 9.573*** | 9.374*** |
| Oil | 5.955*** | 5.916*** | 8.373*** | 7.529*** |
| Electric | -0.777 | -0.757 | 0.707 | 0.645 |
| Solid fuel | 3.070* | 3.059** | 3.363*** | 4.586*** |

Standard errors in parentheses, 90% confidence intervals in brackets, *** p<0.01, ** p<0.05, *p<0.1

**Table 9: Discrete BER expenditure elasticities**

| | | Moving to BER rating | | | | | |
|---|---|---|---|---|---|---|---|
| | Avg. weekly energy expenditure | B | C | D | E | F | G |
| Moving from BER rating | | | | | | | |
| B | 34.38 | | 0.023 | | | | |
| C | 36.29 | -0.022 | | 0.061*** | | | |
| D | 38.53 | | -0.057*** | | 0.038* | | |
| E | 35.65 | | | -0.041* | | 0.099** | |
| F | 35.35 | | | | -0.100** | | -0.179*** |
| G | 26.73 | | | | | 0.236*** | |

*** p<0.01, ** p<0.05, * p<0.1

**Table 10: Discrete BER expenditure elasticities and 90% confidence intervals**

| | Moving to BER rating | | | | |
|---|---|---|---|---|---|
| | C | D | E | F | G |
| Moving from BER rating | | | | | |
| C | | 0.063 | | | |
| | | (0.058, 0.068) | | | |
| D | -0.058 | | 0.033 | | |
| | (-0.064, -0.055) | | (0.019, 0.041) | | |
| E | | -0.035 | | 0.103 | |
| | | (-0.044, -0.021) | | (0.093, 0.126) | |
| F | | | -0.104 | | -0.180 |
| | | | (-0.127, -0.094) | | (-0.195, -0.175) |
| G | | | | 0.237 | |
| | | | | (0.232, 0.258) | |

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