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FUEL POVERTY AND WELL-BEING: A CONSUMER THEORY AND STOCHASTIC FRONTIER APPROACH

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JEL Classification D12, I32, Q41

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Fuel Poverty and Well-Being:

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1. Introduction

In recent years, policy makers are increasingly concerned with a particular aspect of poverty in the form of fuel poverty among households. Broadly, fuel poverty refers to the difficulty of maintaining an adequate temperature in a home, as well as having available other essential energy services (Boardman, 1991). Therefore, fuel poverty can have a general poverty as well as an energy dimension (Hills, 2012). Some studies have shown that fuel poverty could affect well-being and may give rise to social exclusion (Lawlor, 2001; Healy and Clinch, 2004; Liddell and Morris, 2010; or Biermann, 2016). Whether fuel poverty and its effect on well-being is only a feature of general poverty or it is also a distinct form of poverty is important for social policy. Related to this is also whether fuel poverty is an objective condition, or it also has a subjective and dimension in the form of peer comparison (Waddams et al., 2012).

In this paper we present a new approach to analyse how fuel poverty affects the well-being of individuals. In so doing, we will also take into account other general poverty variables to capture the "reference group" to which the individual belongs. We present a theoretical model that allows us to capture consumer preferences via modelling of indifference curves. Given that well-being is a relative concept, in the empirical model we propose a frontier model which allows the construction of relative frontier functions based on the best well-being reported by the individuals in the sample.

From an economic viewpoint, analysis of determinants of well-being (or even happiness)[1] of individuals, has attracted a significant interest in recent years. Such analysis has frequently used the concept of Subjective Well-Being (SWB). The increase in surveys containing information on SWB and studies that find this a satisfactory proxy for measuring individual utility (Frey and Stutzer, 2002; Blanchflower et al. 2004), has allowed both theoretical and empirical analysis of the utility function.

[1] There are differences between the two concepts. Stiglitz et al. (2009) state that well-being encompasses different aspects (cognitive evaluations of one's life, happiness, satisfaction, positive emotions such as joy and pride, and negative emotions such as pain and worry).

Most empirical studies of individual happiness are based on micro-econometric functions, where a SWB or happiness function is estimated using probit or logit models. In these models, true well-being is a latent variable and socioeconomic variables (e.g., income and unemployment) are independent variables. This approach is often used to shed light on theoretical assumptions such as whether income and SWB are positively correlated[2] or diminishing marginal utility occurs with *absolute* income (Clark et al., 2008; Frey and Stutzer, 2002). Clark et al. (2008) in a theoretical and empirical review point to importance of *relative* income comparison - in relation to others in a relevant reference group (social comparison) and to oneself in the past (adaptation or habituation), see, e.g., Clark et al., 2015). The notion that well-being is influenced by relativities such as income has been analysed in recent years (see, e.g., Dorn et al. 2007; Ferrer-i-Carbonell, 2005; Luttmer, 2005).

This paper presents a new approach based on the traditional consumer theory (rather than the commonly used production theory based approaches) where our representation of individual's preferences depends on the bundle of goods they have chosen to maximize their utility or well-being. Additionally, in line with the literature discussed earlier, we extend the standard analysis of preferences with the assumption that when evaluating their well-being, individuals also draw comparisons with their peers or persons bearing similar characteristics to themselves.[3] As suggested by van de Stadt et al. (1985), utility may be a relative concept, in that an individual evaluates a bundle of goods by comparing it with bundles of other goods. Therefore, our model also includes, in addition to the bundle of goods chosen by the consumer and other socioeconomic individual variables, variables related to (general and fuel) poverty to capture the "reference group" to which an individual belongs.

In our model, the preferences of individuals are not represented through a standard utility function, but through a distance function. Using a distance function allows to model an indifference curve where different bundles of goods present different levels of utility to an individual (Shephard, 1957; Cornes, 1992). In this paper we are interested in analysing whether the individuals situated above or below the poverty line

[2] Easterlin (1974 or 2010) found that happiness is not associated significantly with per capita GPD in developed countries (Easterlin Paradox).
[3] As Blanchfolwer et al. (2004) pointed out "*people probably compare themselves more with their peers than with Bill Gates".*

represent different preferences, and therefore, exhibit different indifference curves. From policy viewpoint, this allows us to identify target households when designing measures to reduce fuel poverty.

Having developed the theoretical model, we present an empirical analysis of the model using a stochastic frontier approach (SFA) to estimate the indifference curve (frontier) and analyse why some individuals are "inefficient" in terms of maximizing their well-being given the goods available to them, their reference group and other socioeconomic variables. Given that SWB is not a simple concept, and that our objective is to analyse the influence of fuel poverty on well-being, we delimit the analysis by studying the SWB associated with a single aspect of everyday life - i.e. house satisfaction.[4] We apply this novel theoretical methodological approach to the case of Spain. To our knowledge, this is the first paper to address general and fuel poverty using this approach.

The remainder of the paper is structured as follows: Section 2 is a brief review of the literature on fuel poverty and well-being. Section 3 presents the model proposed. Section 4 describes the database and provides descriptive statistics of the sample used from the Spanish Living Conditions Survey (SLCS) survey. Section 5 discusses the main results of the empirical analysis. Finally, Section 6 concludes.

2. General Poverty, Fuel Poverty and Well-Being

The link between general poverty and well-being has been the focus of several empirical studies which conclude, among others, that well-being is positively related with income, with additional income increasing satisfaction at a decreasing rate. However, as Biermann (2016) points out, little is known about the direct impact of fuel poverty on individual welfare. The issue here is how to separate the effects of fuel poverty from general poverty.

There are various definitions with reference to for fuel poverty. The common link between them is the incapacity to affront household fuel costs. Thus although fuel

[4] Blanchflower et al. (2004) point out the distinction between the well-being from life as a whole and the well-being associated with a single area of life (*context-specific* well-being).

poverty may be considered another facet of general poverty, a two-way relationship between them is not necessarily always the case. On the one hand, there may be situations where a household is in fuel poverty although its overall income is above the poverty threshold (e.g. households with high energy costs with respect to total income and/or households which are extremely inefficient in terms of energy usage). On the other hand, there may be households who, due to their income, are categorised as poor but are not poor from an energy point of view (e.g. because their fuel costs are small relative to their total household costs). Romero et al. (2015), analyse the Spanish case and conclude that cases of fuel poverty are concentrated in the poorest households (thus reinforcing the idea that fuel poverty is a component of general poverty). Nevertheless, once the different definitions of fuel poverty are defined and once the results have been analysed to discard biased results, the authors also reveal that almost 9% of the households in fuel poverty are not in fact within the general poverty threshold. This result supports the idea that both concepts, although finely interwoven, may be reflecting different concepts of hardship.

Currently, there are increasingly more incidents reported, many of them fatal, caused by extreme situations where families are, for example, exposed to extremely low temperatures and/or unhealthy conditions related with damp. Therefore, fuel poverty has gained relevance in recent years in Europe as well as in Australia, New Zealand and in the US (see Bouzarowvski and Petrova, 2015 for a review). Several papers analyse income elasticities and suggest that energy services may be characterised as necessity goods (e.g., Romero-Jordán et al., 2016; Jamasb and Meier, 2010a; Meier et al., 2013). The results of the studies, together with the fact that fuel poverty is increasing in developing and developed countries, are arousing interest on the part of researchers and policy-makers alike.

The first studies on fuel poverty were published in UK. Bennett et al. (2002) analyse household data in 1997-1998 where fuel poverty (measured as households that spend more than 10% of their income on fuel) is a function of variables such as income; gas payment methods; state benefits and household type and composition. Jamasb and Meier (2010b) use panel data for 1991 to 2008 to investigate fuel poverty (as ratio of energy spending over income) as a function of several variables that approximate vulnerable households. Beatty et al. (2011) analyse a possible “heat or eat” trade-off.

Based on the idea that a cold weather shock implies that households must spent more than anticipated to keep themselves warm, they find that if weather shock has a large impact on income, a trade-off between heat or eat can occur. Waddams et al. (2012) using a UK survey of 2000 explore the link between an objective (based on expenditure) and subjective (feeling able to afford sufficient energy to keep their homes warm) measure of fuel poverty. Using logit and data-mining techniques, they estimate the probability of being fuel poor. The results indicate that objective and subjective fuel poverty are positively related but in a complex way and both measures should be considered in social policy. Finally, Roberts et al. (2015) analyse fuel poverty in the UK for the 1997-2008 period. Using dynamic models of fuel poverty as a function of the type of housing; personal characteristics; differences in energy prices and temperature across time and space. The study finds that, on average, the experience of fuel poverty in urban areas was prolonged with a higher probability of persistent fuel poverty.

More recently, this issue has gained relevance at European level. Legendre and Ricci (2013) analyse fuel poverty in France for the year 2006 using logistic and complementary log-log regression models in order to analyse the probability of falling into fuel poverty. The results indicate that the proportion of fuel poor people and their characteristics differ significantly depending on the fuel poverty measure used. Also the probability of falling into this form of poverty is higher for those who are retired, live alone, rent their home, use an individual boiler for heating, and cook with butane or propane. Miniaci at al. (2014) discuss a number of ways to define and measure fuel poverty in Italy between 1998 and 2011. Results differ depending on the the fuel poverty measure chosen. Biermann (2016) uses a German panel data to analyse the relationship between subjective well-being and fuel poverty. The results indicate a negative and significant relation between both variables and that the effect of fuel poverty on individual welfare is beyond the effect of mere income poverty.

For Spain, Romero-Jordan et al. (2016) estimate electricity demand in Spain using a quantile regression method and the equivalent variation concept. They find that the welfare loss of an increase in electricity prices is far greater for the poorest households. Romero et al. (2015) study the impact on fuel poverty of several personal and household characteristics for the year 2013 in Spain using a logit model. They find that low-income (and low energy consumption) households, with dependent children or job instability on the part of the household breadwinner are the most vulnerable in terms of the threat of falling into fuel poverty.

As we pointed out, our objective is to analyse the impact of fuel poverty on individual well-being. The literature on well-being and happiness has seen important developments in recent decades in the works of Blanchflower and Oswald (2004), Kahneman and Krueger (2006), Clark *et al*. (2008), Deaton (2008) or Powdthavee (2010) amongst others. These studies use a similar empirical strategy: the definition of a model where the measure of well-being or happiness is a function of a number of factors such as income, health etc. (see Dolan et al., 2008). Binder and Brockel (2012) and Cordero et al. (2016) estimate a measure of efficiency which shows individuals search for the highest level of happiness achievable, given a set of resources. They use a production frontier model using nonparametric techniques. In these studies, happiness is considered as output and resources for obtaining it (income, health, etc.), are inputs.

The idea behind using frontier models in this context is to compare individuals in order to build a happiness frontier with individuals who, ceteris paribus, can achieve the highest levels of happiness with a given level of resources. Once this frontier is built, other individuals can be compared with those already situated on the frontier in order to determine their level of inefficiency when trying to maximise their happiness. Hence, the estimated frontier is a relative construct and not an absolute one. Granted the relative nature of these frontiers models, this methodology is particularly suitable for analysing a relative concept such as SWB. However, given that well-being or happiness are both concerned with individuals, in this paper we propose an alternative frontier model set within a theoretical framework based on consumer theory rather than the commonly used production theory based approaches.

In order to make the sample as homogeneous as possible, we use the data for only one country, specifically Spain. The issue of fuel poverty in Spain began gathering momentum with the Tirado-Herrero et al. (2012; 2014) reports. In the latter report, the authors find several relevant results. In 2012, 17% of Spanish households (12% in 2010) had energy expenses over 10% of their annual income (equivalent to 7 million people).

Additionally, 9% of Spanish households in 2012 (8% in 2010), were unable to keep their home adequately warm during wintertime (equivalent to 4 million people).

One conclusion of these reports is that there are no signs of improvement in fuel poverty in Spain. This is likely due to the combined worsening of energy inefficiency of the residential buildings, the economic crisis and energy prices. For example, average residential electricity prices in Spain increased by 73% during the 2008-2015 period. In the same period, the natural gas bill of the average Spanish household increased by 26% (Eurostat, 2016).[5] Meanwhile, unemployment grew from 8.5% in 2007 to 20.9 in 2015. Although the evolution of energy poverty in Spain has been similar to other indicators of general poverty, general poverty doubled in the period 2007/2013 while fuel poverty tripled in the same period (Bellver, 2015). These findings reinforce the need to examine the link between general poverty and fuel poverty.

3. Methodology

3.1. The theoretical model

Under the assumption of regular preferences (i.e. fulfilling reflexibility; completeness and transitivity), consumer theory usually uses the so-called utility function in order to represent individual preferences. We propose representing consumer preferences using a lesser known but more suitable primal representation of the preferences i.e. using the distance function.

In order to explain the distance functions, and following Deaton (1979) or Cornes (1992), we initially assume the existence of two goods (q_1 and q_2) as presented in Figure 1 in an indifference curve with several combinations of the two goods that give the consumer (individual) an identical level of well-being (W_0) for example q_B. We also assume an arbitrary reference bundle of goods such as q_A (point A in Figure 1) where consumer will be more than able to attain the satisfaction level W_0. As a result, it is possible to define a scalar λ=0A/0B≥1 which represents the largest scalar (λ) by which all goods can be divided proportionally and continue getting the same well-being level W_0. If λ equals one, it implies that the consumer is located on the indifference

[5] This increase is partially due to the inclusion of costs associated with social and environmental policies.

curve (the frontier). A value higher than one implies that the consumer could attain a higher level of satisfaction than W_0 with the current amount of goods (the bundle of goods A).

(INSERT FIGURE 1 AROUND HERE)

Formally, we define a distance function (Shephard, 1953; 1970), which expresses this functional dependence as:

$$D(q,W,z,P) = \max_{\lambda}\{\lambda > 0: W(q/\lambda) \geq W_0\} \quad (1)$$

where D(q,W,z,P) is the distance function and depends on the vector of goods (q). As Clark et al. (2008) point out, economic theory assumes that the relevant measure of well-being is consumption, not income, and income in happiness regressions is "only a noisy proxy for consumption". They also note that income is an overestimate of what is consumed when a person is young (when consumers save) and an underestimate when a person is old (when consumers do not save). Given this and following Headey et al. (2008) we use consumption q in Equation (1). The distance function also depends on well-being (W) and the vector z which captures the socioeconomic characteristics of the individual and household.

Finally, given the aim of the present paper, we also include a set of variables related to poverty (P) with a view to capturing the social class to which the individuals belong. These variables have been included given that the concepts we wish to explain are subjective and relative well-being. Therefore, we could find the differences in the way individuals value their level of well-being. More specifically, we assume that when evaluating their satisfaction (here, satisfaction with their house), they draw comparisons with their equals – i.e. persons bearing similar characteristics as themselves. Thus, individuals with fewer resources do not compare themselves with high-income individuals but with those with incomes more similar to their own. Therefore, it is important to know whether the individual being analysed is in a comfortable economic situation (thereby drawing comparison with similar individuals in reporting their level of subjective satisfaction) or, to the contrary, the individual is in a situation of material deprivation. In the latter case, the subjective needs reported by an individual are expected to be inferior for those with higher income but living in a more demanding environment in terms of deciding on their material needs (Blanchflower et al., 2004).

The distance function (1) has certain properties: it is non-decreasing in q; decreasing in W; and concave and homogeneous of degree one in q. The distance function is also the dual of the expenditure function and measures the distance to the indifference curve. On point B, D (q,W,z,P) takes the value of one when the consumer is on the indifference curve frontier (Figure 1). In contrast, on A the distance function takes a value greater than one. This implies that if a consumer is on point A and achieves a well-being level W_0 they perceive a lower level of well-being than could have been achieved with their bundle of goods. We are interested in analysing whether poverty (or fuel poverty) is the source of this "inefficiency" of the consumer and preventing him/her from reaching the maximum well-being obtainable.

Formally, from (1) we can measure the distance to a point (e.g. point A in Figure 1) to the indifference curve frontier as follows:

$$\frac{1}{\lambda} = D_I \rightarrow \quad \frac{1}{\lambda} = D_I(q, W, z, P), \qquad 0 < \lambda \leq 1 \tag{2}$$

Imposing homogeneity of degree one in q (e.g., q_1) in (2) we obtain:

$$\frac{1}{\lambda q_1} = D\left(\frac{q}{q_1}, W, z, P\right) \tag{3}$$

Taking natural logarithms and rearranging (3) we obtain:

$$\ln\left(\frac{1}{\lambda q_1}\right) = lnD\left(\frac{q}{q_1}, W, z, P\right) \tag{4}$$

$$-\ln q_1 = lnD\left(\frac{q}{q_1}, W, z, P\right) + ln\,\lambda \tag{5}$$

Specifying:

$$-u = ln\,\lambda \tag{6}$$

we have:

$$-\ln q_1 = lnD\ \left(\frac{q}{q_1}, W, z, P\right) - u \qquad (7)$$

From (6) we know that:

$$exp(-u) = exp(ln\lambda) = \lambda \qquad (8)$$

Finally, we define the Well-being Differential Index (WDI) as:

$$\text{WDI}=exp(-u) = \lambda \qquad (9)$$

i.e. WDI indicates, as explained above, the difference between the reported and the potential (located on the frontier) well-being of an individual. The WDI index can take values between 0 and 1, given that *u* is non-negative.

3.2. The empirical model

In this section we propose an empirical model that allows us to distinguish between the reported well-being and the potential well-being, i.e. the maximum well-being that other individuals have attained with the same bundle of goods and with similar individual and household conditions. In order to do this, we propose a frontier model. The main assumption of this approach is that the reported well-being is equal to the maximum level that the individual could attain (potential well-being) minus an error term that captures this difference.[6] That is, the error term measures the distance to the well-being potential (located on the frontier).

For the empirical model, it is necessary to choose a functional form for the distance function. For modelling individual preferences, basic forms such as Cobb-Douglas, CES, LES (Stone-Geary) impose stringent restrictions on preferences and demand functions. Therefore, and following Jorgenson and Lau (1975), we propose a flexible functional form, i.e. a transcendental logarithmic (translog) function which is a second-order Taylor series approximation of the real, although unknown function. Under these hypotheses the distance function in (7) can be expressed as in (10):

[6] In production literature this term is called technical inefficiency.

$$
\begin{aligned}
-\ln q_{1i} = {} & \alpha_0 + \alpha_w \, ln\, W_i + \frac{1}{2}\alpha_w \, ln\, {W_i}^2 + \sum_{j=2}^{3} \beta_j \ln\left(\frac{q_{ji}}{q_{1i}}\right) \\
& + \frac{1}{2}\sum_{j=2}^{3}\sum_{k=2}^{3} \beta_{jk} \ln\left(\frac{q_{ji}}{q_{1i}}\right) \ln\left(\frac{q_{ki}}{q_{1i}}\right) + \sum_{j=2}^{3} \beta_{jw} \ln\left(\frac{q_{ji}}{q_{1i}}\right) ln\, W_i \\
& + \sum_{AACC=1}^{19} \alpha_{AACC} AACC \;\; + \sum_{c=1}^{C} \alpha_C C + \sum_{h=1}^{H} \alpha_H \, H + \sum_{p=1}^{2} \alpha_p P + v_i \\
& - u_i \qquad\qquad (10)
\end{aligned}
$$

where q and W represent goods and well-being respectively; subscripts j and k refer to goods, and i refers to individuals. *AACC* are regional dummies and C; H and P are variables or dummies representing consumer, household or poverty characteristics respectively. Finally, α's and β's are the parameters to be estimated.

In (10) the quantities of goods that appear as right-hand-side regressors could be endogenous as they are influenced by individuals' unobserved personality traits and other unobserved characteristics. Note, however, that they appear in (10) as ratios. Thus, the ratio of quantities of two goods becomes an exogenous variable (Coelli, 2000; Kumbhakar, 2011). That is, by imposing the distance function property of homogeneity of degree one in goods, we obtain consistent estimates, despite the endogeneity of these goods. Thus, although in our theoretical model, goods are considered as endogenous variables, the omission of these variables does not cause endogeneity problems.

3.3. Modelling inefficiency

In Equation (10) we specified a SFA model where the error is a composed error term and v_i is assumed to be normally distributed.[7] Also, u_i ($u \sim N^{+}(0, \sigma_u^2)$) is associated with the WDI in (9) and represents the excess of the goods that an individual

[7] A distance function frontier can be deterministic or stochastic. In a deterministic frontier, the error component is attributable to the difference between the potential and the reported well-being. In contrast, stochastic frontiers, apart from the term that captures the distance to the frontier, include a random error component, allowing for incorporation of the effects of the statistical noise common to economic data (see, e.g., Kumbhakar and Lovell, 2000).

uses to reach a given level of well-being with respect to the bundle of goods required without loss of well-being. That is, u represents the difference between the potential and the reported well-being, or in the same way, the distance of a point such as A to the indifference curve (frontier). In order to model how fuel poverty influences the distance to this frontier, we specify the variance of u ($\sigma_u{}^2$) as a function of the variables related with the definition of fuel poverty. The larger the variance of the error term u, the greater is the average distance from the frontier (see Caudill et al., 1995 for details). Formally, the relationship between fuel poverty and $\sigma_u{}^2$ is defined as follows:

$$ln\, \sigma_{u_i}^2 = f(fuel\, poverty\, factors) \qquad (11)$$

By estimating (10) jointly with (11), we are able to analyse how fuel poverty can influence individuals in such a way that they are unable to achieve their relative potential well-being level (defined as the maximum well-being obtained for individuals with the same goods and similar individual and household characteristics).

4. Data

In order to estimate the proposed model (Equations 10 and 11), we use a well-being measure; goods related with dwellings and other variables related to individual and household characteristics. We use data from the Spanish Living Conditions Survey (SLCS) which is an annual survey of households. This survey belongs to the set of statistical operations that are harmonized for the European Union member states. The SLCS focuses on providing information regarding several individual aspects such as income; education; well-being and poverty indices. Also, it contains data at household level (e.g. the household members; information on the dwelling, equipment or household income and other relevant economic information).

We use the survey data for the year 2013 because only for this year there is a special well-being module that is particularly relevant for the purpose of our study.[8] The sample contains panels each representing a family and with observations made up of

[8] This implies that is not possible to know how the past could affect today's well-being and individual behaviours (see, e.g., Clark et al, 2015).

family members within each panel (members over 16 years). Our sample consists of 16,608 individuals who were interviewed in 2013. Table 1 shows the definitions and summary statistics of the variables.

(INSERT TABLE 1 AROUND HERE)

SLCS collects information on the well-being of individuals from several points of view. For each welfare measure of individual, it assigns a score of zero (not at all satisfied) to 10 (completely satisfied). Using this information, we construct a composite index that reflects different aspects of well-being in a household (economic satisfaction at home; surroundings). From this index, we built a continuous variable called WELL-BEING which is the weighted average of these indices (see Table 1a). On the other hand, as explained in Section 3, in order to maximize their well-being, individuals choose a number of goods related to dwelling. Therefore, we need to approximate these goods. We approximate electricity consumption (ELECT); gas consumption (GAS) and other household goods (OTHERS) using the expenditures incurred for these. Moreover, and in an attempt to capture the influence of the environmental factors on well-being, we include 19 dummy variables of the Spanish Autonomous Communities defining a dummy variable (AACC) to capture the unobservable invariant aspects specific to each region, such as temperature and differences in prices (see Table 1b for details).[9]

In addition, we use other variables that may affect well-being including the following individual characteristics (for details, see Table 1c and Table 1d): AGE; GENDER, NATION (nationality); CIVIL STATUS; EDUCATION; CHRONIC (whether the individual has, or not, a chronic disease) and JOB STATUS (one week preceding the survey). We also include variables reflecting household characteristics: HTYPE (type of home); HTENURE; HROOMS; HURBAN (whether the home is situated or not in a populated zone); HBUILDING (type of building) and the variable OLD (proxy of the age of the building) which approximates the energetic (in)efficiency of the households.

[9] Given that we use dummies for regions (AACC) and a model in logarithms terms, expenditures are a good proxy of consumption if we assume that the prices of these goods are the same in a region.

Moreover, well-being is a relative and subjective concept, given that individuals evaluate a bundle of goods by comparing it with other bundles of goods. In this sense, the bundle of goods necessary to achieve a certain level of well-being may be different for low and high income individuals. In order to control for this we include a poverty-related variable in the model in the form of a general poverty index: MATDEP which indicates if an individual is at risk of social exclusion. This index is a statistical term defined by OECD that refers "to the inability for individuals or households to afford those consumption goods and activities that are typical in a society at a given point in time, irrespective of people's preferences with respect to these items".[10] Although this also includes subjective and objective variables related with fuel poverty, this index is primarily a measure of general poverty. As a result, and given that we are mainly interested in the effect of fuel poverty on well-being, we include some complementary measures of fuel poverty. This issue is addressed in the next section.

4.1 Measuring fuel poverty. The Case of Spain

Fuel poverty indicators can be based on both objective measures as well as subjective perceptions of it. Regarding objective measures, for many years, the UK used the 10% rule (i.e. a household is fuel poor if it uses more than 10% of its income on energy costs). In recent years, fuel poverty in England has been measured using the Low Income High Costs (LIHC) indicator proposed by Hills (2012) while Wales and Scotland continue to use the 10% rule. LIHC indicator defines fuel poverty as the combination of facing high costs and having a low income. This approach means setting two thresholds – one for income and one for costs. Moore (2012) defines the MIS indicator (*Minimum Income Standard*) which refers to the minimum income of a

[10] The index refers "to a state of economic strain defined as the enforced inability (rather than the choice not to do so) to acheive at least 4 items from a list of 9: to pay unexpected expenses; afford a one-week annual holiday away from home; a meal involving meat, chicken or fish every second day; adequate heating of a dwelling; durable goods such as washing machine; colour television; telephone; or vahicle; faced with payment arrears (mortgage or rent, utility bills, hire purchase instalments or other loan payments)".

household which permits its members to opt for opportunities and choices which allow them an active integration in the society.[11]

In Spain, the first initiative for approximating measures of fuel poverty was undertaken by Romero et al. (2015) where the 10% threshold, the MIS indicator and the LIHC are calculated and compared. The study concludes that the use of the MIS index indicates that fuel poverty is present in 8-9% of the Spanish households (1,799,311 households representing, 6,264,432 individuals). Moreover they find that the 18.24% figure obtained with the indicator of "the 10%" includes a high number of false positives. With the LIHC indicator the problem is present in 8.71% of the Spanish households. After calculating the three indicators (10% threshold; MIS and LIHC) and after a comparison of pros and cons of these indices, the report concludes that the MIS indicator offers the best approximation to the problem for Spain. Therefore, we chose this indicator as a measure of fuel poverty. Concretely, and following Romero et al. (2015) we approximate the MIS indicator as the *incomes of social integration* for the different Autonomous Communities in Spain. Once the MIS is approximated, we define the fuel poverty indicator MISRATIO as the ratio of the sum of the MIS and energy expenditures for each household, divided by disposable household income (see Table 1d).[12]

Nevertheless, fuel poverty may be affected by other factors aside from the proportion of energy costs in household budgets, such as high energy prices; temperatures and low energetic efficiency of the household. In this sense, as we have explained, including dummy variables of the Autonomous Communities (AACC) we can control for price differences between the regions, as well as other specific characteristics of each autonomous community such as minimum and maximum temperatures. Moreover, the variable OLD approximates the energetic (in)efficiency of the household.

[11]Specifically, he defines this inequality: *[Household income] - [Living costs] - [Equivalent MIS] > Household energy costs.* If this inequality is not fulfilled, the household is in fuel poverty. In the UK, the platform "*minimumincome.org.uk*", permits the calculation of MIS for households as a function of criteria for the basic needs to which all citizens should be able to accede. This is not possible for Spain.
[12]In contrast to Romero et al. (2015), who use the average of the MIS values (weighed for population of each region), we use different MIS values for different regions.

In sum, the variables included in the model for the purpose of analysing fuel poverty are MISRATIO, OLD, AACC and MATDEP. These variables will be included both in Equation (10) as well as Equation (11). Consequently, Equation (11) can be expressed as:

$$ln\sigma_{u_i}^2 = \delta_0 + \delta_1 MISRATIO + \delta_2 OLD + \sum_{AACC=1}^{19} \delta_3 AACC + \delta_4 MATDEP \quad (12)$$

where δ's are the parameters to be estimated.

5. Results

The estimated maximum likelihood parameters from the estimation of (10) and (12) are presented in Table 2. As regards Equation (10), the continuous variables are divided by their geometric mean which means that the coefficients can be interpreted as elasticities. The model works quite well. In particular, all the first-order parameters have the expected signs (i.e., non-decreasing in the case of household goods and decreasing in the case of well-being), with both proving highly significant, which indicates that the preferences estimated comply with the theoretical requirements.[13]

(INSERT TABLE 2 AROUND HERE)

Firstly, and as we have already explained, in (10) we have included variables relating to material deprivation (MATDEP) and fuel poverty (MISRATIO), in order to capture the reference group to which each individual belongs under the assumption that rich and poor individuals could have different indifference curves.

In section 3.1 we hypothesised that reported needs could be inferior for an individual who is in material deprivation than another individual with higher income but

[13] First-order coefficients do not have a direct interpretation. Their interpretation is complex and its details are beyond the scope of this paper.

living in a more demanding condition. The results confirm our expectation. Poor persons require fewer goods than persons with a greater purchasing power in order to achieve a similar level of well-being. More specifically, and according to the coefficient of MATDEP, individuals in material deprivation need 4.4% less household goods to obtain a similar level of satisfaction to an individual who does not suffer from severe material deprivation. Moreover, the result for the fuel poverty variable is interesting given that, even taking into account material deprivation, being in a situation of fuel poverty moves the indifference curve significantly. Concretely, if the MISRATIO index increases by 1%, individuals reduce, ceteris paribus, their bundle of goods by 0.13%.

Regarding the individual and household characteristics, Table 2 presents the coefficients of the variables estimated. For example, we can analyse the impact on well-being of owning a house without a mortgage versus having a mortgage or renting. The coefficients related to this variable are negative and significant, indicating that, as expected, the individuals with mortgages or rents enjoy a lower level of well-being than those who own their house, given the same living costs (gas, energy and others) and similar personal and housing characteristics. Specifically, a household with a mortgage spends 45.1% more on household goods to achieve a similar level of well-being as the individual owning a house without a mortgage. Similarly, an individual renting at market prices incurs 64.5% more in costs than the aforementioned individual. Finally, if the individual is renting at a lower than market price or is in a house free of charge, they still spend 3.1% more than the individual previously mentioned.

Moreover, the type of dwelling also influences well-being. Living in a flat implies expenditure which is 2.4% greater in order to obtain the same level of well-being as an individual living in a detached or semi-detached, given similar individual and housing characteristics. Lastly, with identical personal and housing characteristics, an increase of 1% in the number of rooms implies 0.15% more expenditure in order to maintain the same level of well-being. Dwellings in which people are under 65 years of age and live alone require fewer resources than other types of dwellings. For example, individuals older than 65 living alone need 4.4% less than the previous case. In contrast, households with two adults and with dependent children need 51.5% more resources. Also, in line with Roberts et al. (2015), living in an under-populated zone increases well-being, requiring 12.8% less expenditure than in the case of houses situated in heavily populated zones. Finally, the variable OLD (whether households have leaks or lack toilets inside the dwelling), is not significant, likely due to the interrelationship between this variable and the two measures of poverty.

With respect to the individual's variables, women, ceteris paribus, need to purchase 1.5% more than men in order to obtain a similar level of well-being. Europeans require more goods (5.4%) than Spaniards, while Non-Europeans need 2% less. Single persons need less housing goods than individuals with another marital status to feel satisfied with their house. This difference ranges from 6.9% less in the case of married persons to 14.6% less in the case of divorcees.

The results indicate that individuals with more education are more demanding in terms of the needs of their household and in turn, these demands increase with the level of education - from 5.1% for secondary education (first cycle) to 14.4% for university education. Regarding employment status, unemployed people need to conform to 4.3% less than the employed people. In contrast, retired people need 2% more than people currently employed, ceteris paribus. People with chronic disease need to purchase 1.8% more than healthy people. Finally, once we control for other socioeconomics characteristics, the age variable does not seem to be significant in explaining SWB for a household.

Equation (12) allows us to analyse the effect of fuel poverty on well-being. The results are reported in Table 3. Let us recall that increases in the variance of u represent increases in the distance to the indifference curve "the frontier" (and vice versa). With reference to Figure 1, we are analysing individuals who are on a point such as A where they obtain a SWB equal to W_0, whereas they could obtain a higher level of utility than W_0.

(INSERT TABLE 3 AROUND HERE)

The results indicate that general (MATDEP) and fuel poverty (MISRATIO) have a positive and significant sign, indicating that both concepts explain these losses of well-being. These results imply that once we control for material deprivation, individuals suffering from fuel poverty tend to achieve a lower level of well-being than those who are not fuel poor. That is to say, if the energy expenditures jointly with minimum standard income represent an important percentage of disposable income, this implies that individuals have to forgo other goods which are useful in satisfying their other needs - to some degree, this result captures a type of substitution effect between "household basic goods" and other goods (e.g., leisure goods). It thus implies a reduction in the well-being of an individual because as a result of being in a fuel poverty situation. On the other hand, and as was the case with the indifference curve, the variable OLD is not significant perhaps because of the close relationship between this variable and poverty variable.

Once (10) and (12) have been estimated, we can calculate the Well-being Differential Index (WDI) for each individual as expressed in Equation (9) above. As previously explained, the value of these indices ranges between 0 and 1. An index value equal to one indicates that the individual reaches 100% of his/her relative potential well-being, given their bundle of goods and characteristics. In contrast, a value of the index close to 0 would mean that the individual is far from their potential well-being.

As shown in Table 4, the value of the WDI at the mean is 87%. This means that, at the mean, individuals possess a below-potential level of well-being, based on a given goods endowment and the characteristics of the consumers and as such, they require 13.1% more resources to reach their full well-being potential.

(INSERT TABLE 4 AROUND HERE)

Finally, Figure 2 shows the relationship between WDI and the fuel poverty index (MISRATIO). The results confirm those obtained in Table 3: even when controlling for general poverty, a situation of fuel poverty increases the distance to the indifference curve, implying greater welfare losses than for those individuals who are not subject to the said situation.

(INSERT FIGURE 2 AROUND HERE)

6. Conclusions and Policy Lessons

In this paper we have developed a new approach to analyse how general poverty and fuel poverty affect the well-being of individuals. The theoretical model allows us to capture consumer preferences via the modelling of indifference curves. Taking into account that subjective well-being and poverty tend to overlap to some degree, in the empirical model we propose a frontier model which permits the construction of relative frontier functions based on the best practices of the individuals in the sample.

In contrast to previous studies which have used production-based approaches to analyse happiness or SWB, we use a theoretical framework based on consumer theory. The proposed model permits estimation of individual indifference curves which take into account their consumption of goods, personal characteristics and the surroundings. Moreover, the distance function approach allows us to estimate the model consistently, even when goods can be endogenously determined by the individual, given that these are a function of personal characteristics such as personality and motivations.

We apply the theoretical model empirically using data from the 2013 Spanish Living Conditions Survey (SLCS) survey. The results indicate firstly, that individuals' preferences differ depending whether the individuals are in a situation of poverty. This is true for the two poverty concepts analysed: general poverty and fuel poverty. In terms of our theoretical model this is reflected by the different indifference curves. That is, individuals adapt their needs to their possibilities, so that the expenditure required to obtain a given level of utility is lower in the case of consumers who are in a poverty situation. Furthermore, the effect of fuel poverty (as shares of basic and energy expenditures of disposable income) on SWB persists even when controlling for general poverty, which indicates that they reflect different effects and, therefore, it is preferable to analyse them separately.

Secondly, we analysed the factors that cause individuals not to reach their maximum level of well-being with a given bundle of goods, personal and household characteristics as well as those of the reference group to which they belong. These results indicate that both, being in a situation of general poverty and fuel poverty, explain these losses in well-being. We show that poverty has a negative and significant effect on individuals' welfare. Although this is not new, we show that “fuel poverty” (a feature of general poverty) influences the welfare of individuals in a different and significant way. It is important to undertake measures to address fuel poverty which is rising faster than general poverty. In Spain, various measures have been developed to eradicate fuel poverty both at national, regional and local level. At national level, a “bono social” discount of 25% on electricity bills has been provided for some consumer groups. However, this has been regarded as being insufficient for addressing the problem.[14]

A relevant question is what are the most efficient and equitable measures to address this problem. Lump sum payments as opposed to price supports have economic properties that can make this mechanism part of the solution. Direct payments have also been used as part of subsidy reduction programs. The analysis of the Well-being Loss Index (WLI) in Table 4 show that, in order for an individual in general poverty to reach the same level of well-being of one who is not in that situation, they should receive an increase in income equivalent to 6% of their household expenditure (WLI=0.81 for poor people versus WLI=0.87 in other case).

With respect to fuel poverty, an individual with a percentage of basic household expenses (including electricity) which is high (decile 9), would need to be compensated with 5% of their expenses in order to obtain the same level of well-being as a household at decile 1. This difference increases to 10% when we analyse individuals in extreme fuel poverty (decile 10). Only a movement of one decile doubles the compensation required. This result indicates that the loss of welfare is not linear and that a possible “compensation” would be more efficient (in terms of increasing the welfare of an individual), if it is focused more on households who are in fuel poverty. Although it may be necessary to take the effects of other socio-economic factors into account, the proposed approach may prove a first step towards better understanding and designing measures to mitigate the impact of fuel poverty on individual welfare.

[14] However, only 20% of the users entitled to “Bono Social”, are in need of it given their income levels. According to the “Comisión Nacional de los Mercados y la Competencia” (National Securities Market Commission), at the end of 2013 a total of 2,509,030 consumers were eligible for the “Bono Social”. Of these, the majority, 80% were eligible for the” Bono Social” because they had contracts for up to 3 kW, that is, without taking into account any income criteria. The remainder of beneficiary groups of the “Bono Social” such as pensioners (11.2%), large families (5.8%) and households with all their members in a situation of unemployment (1.7%), only amount to 500,000 households. Moreover, this only affects the electricity bill and does not include other types of energy.

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Figures

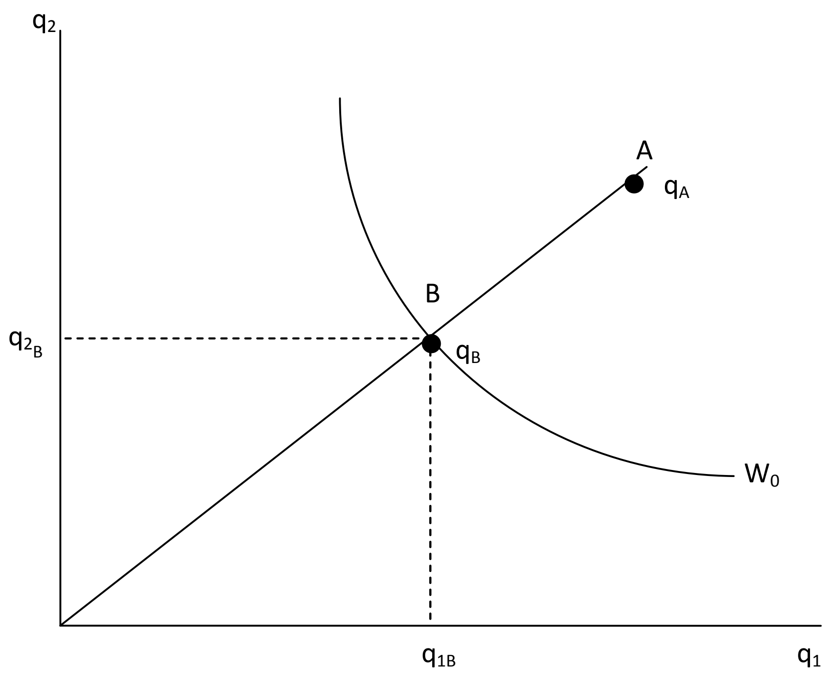
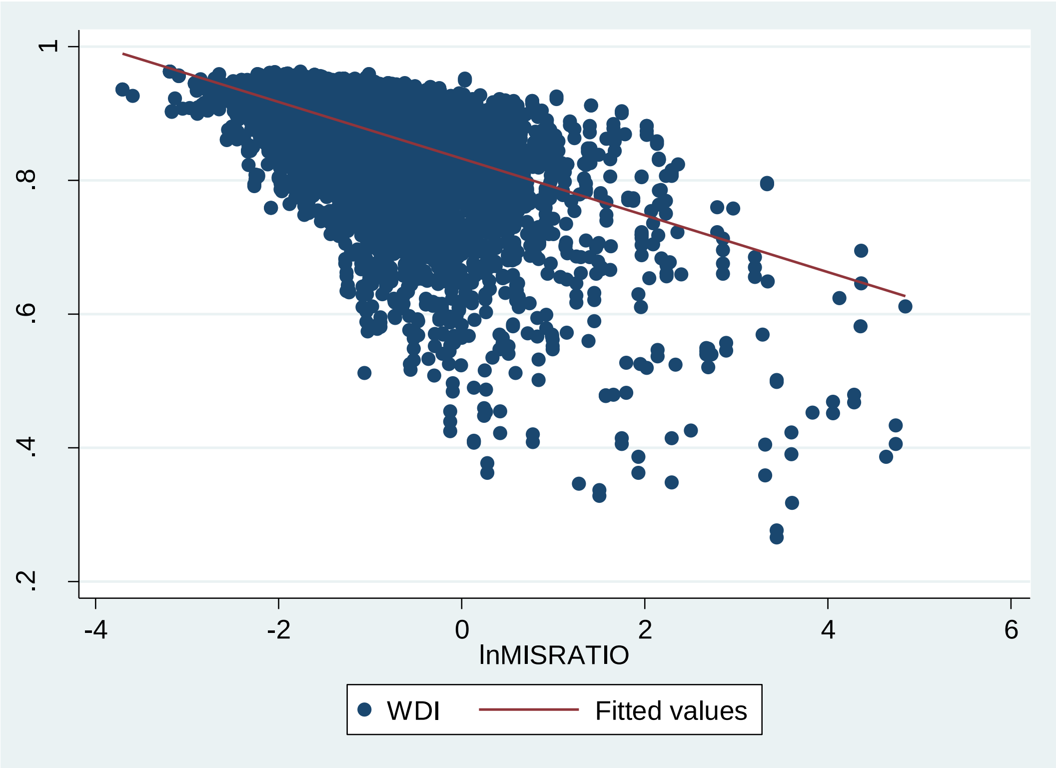


Figure 1: The distance function

Figure 2: Relationship between the WDI index and Fuel Poverty



Tables

Table 1: Variables Definitions

Table 1a: Well-being measure

Variable	Definition	Mean	S.D
WELL-BEING including:	Indices take values from 0 to 10.	6.74	1.53
▪ Satisfaction with the economic situation at home		5.76	2.18
▪ Satisfaction with the house		7.32	1.82
▪ Satisfaction with the recreational areas or green area where you live		6.6	2.34
▪ - Satisfaction with the quality of the area where you live		7.23	1.92

Table1b: Goods related with the household

Variable	Definition	Mean	S.D
ELECT	Electricity consumption is approximated by expenditures on electricity per consumer units* at home (€ 2013)	413.4	226.8
GAS	Gas consumption is approximated by expenditures on gas per consumer units* at home (€ 2013)	315.5	278.3
OTHERS	Other household goods consumption is approximated by expenditures in other household per consumer units* at home (€ 2013)	1240.9	1219.6
AACC	Dummy variables for each of the Spanish autonomous communities plus two autonomous cities (19 dummies in total)	N/A	

Following OCDE scale, consumer units (CU) are calculated as: CU=1 + 0.5 x (household members older than 13 years - 1)* + 0.3 x (household members under 13 years).

Table1c: Individual characteristics

Variable	Definition		
		Mean	**S.D**
AGE	Age	50.0	18.5
		%	
GENDER	1 Man 2 Woman	47.81 52.19	
NATION Nationality	1 Spain 2 Rest of Europe 3 Rest of the world	92.2 1.9 5.9	
CIVIL STATUS	1 Single 2 Married 3 Separated 4 Widowed 5 Divorced	29.4 56.7 1.9 8.6 3.4	
EDUCATION Education completed	1 Primary Education 2 Secondary education I 3 Secondary education II 4 Professional formation 5 Higher education	26.7 27.1 21.3 0.2 27.8	
CHRONIC	=1 chronically ill =0 otherwise	33.81 66.2	
JOB STATUS	=1 Working =2 Unemployed =3 Retired =4 Other kind of labour inactivity	40.36 16.30 18.45 24.88	

Table1d: Household characteristics

Variable	Definition	Mean	S.D
HROOMS	Number of rooms	4.93	0.94
MISRATIO	Based on MIS, the fuel poverty indicator is defined as: (household MIS+Household energy costs)/ Household income	0.65	3.96
		%	
HTYPE Type of home	1 One person: under 65 years of age 2 One person: over 65 years of age 3 Households with two adults without children and others. 4 Households with two adults with children	3.94 4.41 47.42 44.22	
HTENURE	1 Owned without a mortgage 2 Owned with mortgage 3 Rent or sublet at market price 4 Rent or sublet at a below market price	57.32 27.08 7.60 8.00	
HURBAN Degree of urbanization	1 Very populated zone 2 Average Zone 3 Sparsely populated area	46.89 21.16 31.95	
HBUILDING Type building	1 Detached or semi-detached house 2 Apartment(storey)	40.26 59.74	
OLD	=1 if there are housing problems involving leaks, damp walls, floors, ceilings or foundations, or rotten floors, window frames or doors, or if there is not toilet inside the dwelling) =0 otherwise.	17.67 82.33	
MATDEP	Household in severe material deprivation* =1 yes =0 otherwise	5.11 94.89	

Table 2. Estimation of the stochastic distance frontier (Equation 10)

Variables	Coeff.	t-stat.	Prob.	Variables	Coeff.	t-stat.	Prob
ln(ELECT)	0.390	79.250	0.000	**EDUCATION 2 (Second I)**	-0.051	-6.270	0.000
ln(GAS)	0.167	45.130	0.000	**EDUCATION 3 (Second II)**	-0.106	-11.780	0.000
ln(OTHERS)	0.443	88.800	0.000	**EDUCATION 4 (PF)**	-0.090	-1.570	0.115
ln(WELBEING)	-0.069	-6.170	0.000	**EDUCATION 5 (Univers)**	-0.144	-15.350	0.000
ln(ELECT)2	0.060	8.260	0.000	**CHRONIC 1**	-0.018	-2.820	0.005
ln(GAS)2	0.037	7.940	0.000	**HTYPE 2 (Person >65)**	0.044	2.130	0.034
ln(OTHERS)2	0.002	0.320	0.752	**HTYPE 3 (no children)**	0.377	25.970	0.000
ln(WELBEING)2	-0.009	-5.640	0.000	**HTYPE 4 (with children)**	0.515	34.150	0.000
n(ELECT)ln(WELBEING)	0.025	3.600	0.000	**TENURE 2 (with mortgage)**	-0.451	-56.280	0.000
ln(GAS)ln(WELBEING)	-0.053	-6.490	0.000	**ENURE 3 (rent market price)**	-0.645	-44.000	0.000
ln(ELECT)ln(OTHERS)	-0.012	-2.190	0.029	**ENURE 4 (rent < market price)**	-0.031	-2.950	0.003
(OTHERS)ln(WELBEING)	0.027	4.260	0.000	**ln(ROOMS)**	-0.153	-11.080	0.000
ln(GAS)ln(OTHERS)	0.010	2.750	0.006	**HBUILDING 2 (flat)**	-0.024	-3.450	0.001
ln(GAS)ln(ELECT)	-0.048	-10.370	0.000	**URBAN 2 (low urban)**	0.025	3.400	0.001
ln(AGE)	-0.013	-0.810	0.417	**URBAN 2 (no urban)**	0.128	16.490	0.000
ln(AGE)2	-0.022	-0.960	0.335	**MISRATIO**	0.131	15.840	0.000
GENDER (Woman)	-0.015	-2.650	0.008	**MATDEP 1**	0.044	1.800	0.072
NATION 2 (European)	-0.054	-2.740	0.006	**JOB STATUS 2 (unemployed)**	0.043	5.230	0.000
NATION 3 (Rest World)	0.020	1.510	0.132	**JOB STATUS 3 (retired)**	-0.020	-1.800	0.071
IVIL STATUS 2 (Married)	-0.069	-7.620	0.000	**JOB STATUS 2 (others)**	0.003	0.350	0.729
CIVIL STATUS 2 (Separt)	-0.081	-3.900	0.000	**OLD**	0.019	1.420	0.157
CIVIL STATUS 2 (Widow)	-0.077	-5.110	0.000	**constant**	0.246	6.170	0.000
IVIL STATUS 2 (Divorced)	-0.146	-8.990	0.000				

Notes: 16,608 observations.
Equation (10) includes 19 dummy variables for regions (AACC) that are not reported in the table.

Table 3. Determinants of the difference between perceived & potential well-being (Equation 12)

Variables	Coeff.	t-stat.	Prob.
MIS RATIO	0.732	9.660	0.000
MATDEP	0.427	2.010	0.044
OLD	0.034	0.210	0.833
constant	-3.757	-6.080	0.000

Note: Equation (12) includes 19 dummy variables for regions (AACC) that are not reported in the table.

Table 4. Estimated Well-being Loss Index (WLI)

	Observations	Mean	Min	Max
WLI (TOTAL)	16,608	0.8705	0.2685	0.9611

	Observations	Mean	Min	Max
WLI (MATDEP)				
MATDEP=0	15,839	0.8730	0.2657	0.9632
MATDEP=1	769	0.8151	0.3178	0.9413

	Observations	Mean	Min	Max
WDI (deciles)				
D1	1,660	0.9010	0.7481	0.9633
D2	1,661	0.8923	0.7195	0.9581
D3	1,661	0.8865	0.6108	0.9528
D4	1,660	0.8865	0.6108	0.9528
D5	1,661	0.8759	0.5122	0.9590
D6	1,661	0.8726	0.5806	0.9459
D7	1,661	0.8695	0.5940	0.9453
D8	1,661	0.8610	0.5171	0.9417
D9	1,661	0.8529	0.5078	0.9399
D10	1,661	0.8057	0.2658	0.9526