



Energy efficiency and the role of energy-related financial literacy: evidence from the European residential sector

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Received: 22 May 2020 / Accepted: 22 February 2021
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Abstract In this paper, we analyze the level of efficiency in the use of electricity in the European residential sector relying on a cross-sectional data set comprised of 1375 households located in Italy, the Netherlands, and Switzerland and observed in 2016. To do this, we estimate an electricity demand frontier function using a stochastic frontier approach. The empirical results show that the residential sector in these three European countries could save approximately 20% of its total electricity consumption on average if it improves the level of efficiency in the use of electricity. These figures are in line with recent studies for Switzerland and for the US residential sector. Moreover, we link energy efficiency to energy-related financial literacy. We find that while energy-relevant knowledge per se does not play a significant role, stronger cognitive abilities are associated with higher levels of energy efficiency.

Keywords European residential electricity demand · Energy demand frontier function, Household data

JEL classification D1 · D12 · D13 · Q41

Introduction

EU countries have agreed on a 2030 framework for climate and energy, which sets new and challenging targets for the European Union post-2020 low carbon framework. Among these targets is a binding commitment to improve energy efficiency by at least 27% for the year 2030, compared to projections of future energy consumption based on the current criteria. Recently, the commission even increased the energy efficiency target for 2030 to 32.5% within the new Energy Efficiency Directive. As part of the European Green Deal, the proposed targets towards a climate-neutral EU are even more ambitious. Similarly, Switzerland set high targets such as a reduction in energy consumption of 43% until 2035 compared to 2000 levels and a reduction of greenhouse gases by 50% until 2030 compared to 1990 levels.

Improvements in energy efficiency represent an essential strategy to meet the long-term 2050 greenhouse gas reduction targets. Moreover, saving energy through investments in energy efficiency is crucial towards achieving a more competitive, secure, and sustainable energy system, and it is an important means to ensure monetary savings (European Commission 2018). In 2016 for example,

This article is part of the Topical Collection on Consumer energy efficiency decision making across sectors

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households across the world saved 10 to 30% of their annual energy spending due to energy efficiency gains (IEA 2017).

Technological change and innovations are important drivers of energy efficiency (Gillingham and Palmer 2014). Nowadays, new technology is available at a low cost. To improve the adoption of new energy-efficient technologies, regulatory approaches such as codes and standards have been extensively adopted (Gillingham et al. 2009). However, big challenges still remain in the process to achieve the energy efficiency targets. Firstly, at the moment mandatory codes and standards have been adopted to cover only one-third of global energy use (IEA 2017). Secondly, energy efficiency depends not only on the availability of cheap technologies or policy interventions but is also largely influenced by individual-specific behavior (Gerarden et al. 2017). Improvements in energy efficiency ensure a reduction in consumers' energy bills and at the same time address the negative externalities associated with high energy use. Although consumers are likely aware of these advantages, the adoption of energy-efficient appliances is often low, as households may choose to postpone substituting old and inefficient durables that consume a lot of electricity. Moreover, appliances such as cooling systems or washing machines are often used in a non-optimal way. Such energy-inefficient behaviors are the consequences of a multitude of barriers.

Schleich et al. (2016) distinguish between external and internal barriers. External barriers are typically factors external to the agents that mainly depend on institutional settings. These barriers can take the form of (1) capital market failures, such as liquidity constraints, and (2) information problems, such as lack of information on product availability and energy-efficient attributes. Not only a lack of information but also asymmetric information, as well as split incentives between a principal (for example the landlord) and an agent (tenant), often prevent investments in energy-efficient appliances. Finally, financial and technological risks may represent a third external barrier to energy efficiency. These risks are connected to the uncertain profitability of new investments, due to their uncertain technological performance, and unpredictable fluctuations in fuel prices.

However, even if these market failures could be overcome, other barriers that have to do with factors related to individual preferences and behavior may still exist. These barriers are labeled internal in the taxonomy provided by Schleich et al. (2016). Time, risk, and environmental preferences, along with loss aversion and risk aversion (due to

reference-dependence and non-linear probability weighting), rational inattention, present-bias, myopia, and status-quo bias, potentially reduce the level of efficiency in a household's energy use. As discussed in Blasch et al. (2017b), another possible reason for people not to see and pick up the low-hanging fruit of energy efficiency is associated with bounded rationality. In order to choose between two appliances with the same functionality, a rational, utility-maximizing consumer should choose the one that minimizes lifetime cost (i.e., the sum of the purchase price and future energy costs). However, in order to perform this optimization, specific forms of literacy are needed, which Blasch et al. (2021) named energy-related financial literacy.¹ An optimal decision from an economic point of view requires both specific knowledge (e.g., of the purchase prices of the two appliances, their electricity consumption, their expected lifetime, the expected intensity and/or frequency of use, as well as current and future electricity prices) and specific cognitive skills, which include the ability to calculate the lifetime cost of the two appliances. The concept of energy-related financial literacy combines the energy-relevant knowledge and the cognitive skills to perform an investment calculation that households need to take informed decisions with respect to energy consumption. However, the theory of "bounded rationality" postulates that some individuals have limited capacities to process information and therefore often fail to make optimal decisions based on rational calculations. Instead, many individuals use simple rules-of-thumb when making their choices.

Given the energy efficiency target previously described, it is important for policymakers to have an estimate of the electricity-saving potential in households. Moreover, it is crucial to know the determinants of the level of efficiency in the use of electricity, and the role of some of the barriers listed above. While the implications of external barriers on energy efficiency are well documented, internal barriers are less studied in this context, and even less so the role of bounded rationality.

In this paper, using survey data from three European countries, we aim to address these issues. In particular,

¹ Following Blasch et al. (2021), energy-related financial literacy is the level of energy-related knowledge and cognitive abilities that consumers need to have in order to take investment decisions related to energy consumption. So far, the academic literature has not developed a common concept of literacy in the context of energy-related investment decision making in the residential sector. For more details, see Blasch et al. (2021).

using appropriate econometric techniques, we answer the following questions: What is the level of efficiency in the use of electricity of European households? How large are potential electricity savings in the residential sector for a specific level of energy services? Which is the contribution of energy-related financial literacy to energy efficiency? Ideally, one should estimate the level of efficiency in the use of all sources of energy at the household level. However, due to difficulties in collecting information on gas and oil consumption, we limit the analysis to the electricity consumption.

One possible way to evaluate the energy efficiency of households is through ex-ante engineering estimates based on bottom-up models. These models require detailed information about the relative efficiencies of various types of energy-using equipment, information of the existing deployment, and assumptions about usage patterns. However, bottom-up models have limitations. For example, they ignore complex interactions, make erroneous assumptions about usage, and face quality control problems, but most importantly, they do not take into account individual behavior (Fowlie et al. 2018; Gerarden et al. 2017). Ex-post evaluations, which utilize information on actual energy usage, represent a better approach to measure energy efficiency and potential energy savings. In this paper, we apply this second approach and estimate a residential electricity demand function using a stochastic frontier approach (Filippini and Hunt 2015). The frontier represents the lowest level of electricity required to obtain a certain level of energy services. Any difference between actual consumption and the frontier demand function is considered inefficiency. To compute this measure, we use information on the observed electricity use.

The contribution of this paper is 2-fold. First, we estimate energy efficiency through a stochastic frontier analysis using disaggregated data from three different European countries. This is the first study that collects micro level data on electricity use, energy services, and other household-level information in different European countries and uses them in a stochastic frontier analysis. The second contribution is that this paper is the first study to link energy efficiency and energy-related financial literacy, decomposing literacy into two components. In particular, using the electricity demand frontier approach, this paper informs on the role of energy-related knowledge and of cognitive abilities (which should be highly correlated with not being boundedly rational) independently on the level of efficiency in the use of electricity.

The rest of this paper is organized as follows. In the next section, we provide an overview of the literature. In the “A model of electricity demand” section, we develop a model for the estimation of the level of efficiency in the use of electricity in European households. In the “Data” section, we describe the household survey data. The results we present in the “Results” section. In the final section, we offer concluding remarks.

Review of the literature

Our work is related to two strands of literature. The first is the literature on measuring energy efficiency which uses stochastic frontier methods. Stochastic frontiers were originally applied to analyze economy-wide energy efficiency using aggregate energy consumption data for the whole economy. Filippini and Hunt (2011) model energy efficiency for an unbalanced panel of 29 OECD countries from 1978 to 2006, controlling for income, price, population, and weather variables that affect energy demand. Zhou et al. (2012) use cross-sectional data for 21 OECD countries. Lin and Du (2013) examine the efficient use of energy for 30 Chinese administrative regions from 1997 to 2010.

Other papers apply aggregated data to study energy efficiency but focus on the residential sector. Filippini and Hunt (2012) use residential aggregate energy consumption for the 48 US states over the period 1995 to 2007. Otsuka (2017) analyzes residential electricity energy efficiency using data from 47 prefectures in Japan from 1990 to 2010. Filippini et al. (2014) utilize data for 27 EU member states for the period from 1996 to 2009 and assess the contribution of policies on energy efficiency improvements in the residential sector. The paper finds that while financial incentives and energy performance standards promote energy efficiency, information-based measures such as labeling and educational campaigns are less effective.

More recent papers were able to circumvent the data limitations of early analyses and apply stochastic frontier analysis to the residential sector using disaggregated data at the household level. Weyman-Jones et al. (2015) use cross-sectional survey data to analyze the level of efficiency in the use of electricity for Portuguese households. Broadstock et al. (2016) estimate stochastic electricity demand frontier functions for a cross-sectional sample of more than 7000 Chinese households. Moreover, Boogen (2017) estimates the level of efficiency in

the use of electricity for Swiss households using cross-sectional data from two survey waves in 2005 and 2011.

Further improvements were made in Alberini and Filippini (2018). The authors assembled a large panel data set for the US households from 1997 to 2009. Applying panel data, the authors decompose the level of energy efficiency into a persistent and a transient component. The persistent part exists due to the presence of structural problems or systematic behavioral failures. The transient part, on the contrary, can be solved in the short-term as it is mainly due to the presence of non-systematic minimization problems. The authors use a novel econometric approach which was originally applied by Filippini and Greene (2016) to study productive efficiency of railway companies.

Relevant to our paper is a second strand of literature on the role of bounded rationality on some measures of energy efficiency. There are limits to human capacity to process and evaluate information. Therefore, in complex situations, people rely on a simple counting heuristic and rules-of-thumb that help to simplify the decision-making process. Camilleri and Larrick (2013) provide evidence of the link between bounded rationality and energy efficiency. They find that individuals can better process information on fuel consumption rather than fuel costs when they need to choose between more efficient vehicles. They also find that providing a more comprehensive mileage scale helps the decision process, because decision-making is facilitated if the problem representation matches the problem-solving processes. Ungemach et al. (2017) confirm that people often apply simple heuristics when choosing between cars. The use of multiple translations of energy efficiency metrics could help to guide behavior in favor of energy-efficient choices.

Some papers directly study the role of energy and investment literacy with respect to energy efficiency. Brounen et al. (2013) find that a joint index of energy awareness and ability to adequately make financial decisions is unrelated to energy consumption and conservation behavior. Blasch et al. (2017a) are the paper that most closely relates to the present analysis. The paper follows the energy demand frontier approach using household-level data in Switzerland from 2010 to 2014. Moreover, it provides an empirical analysis of the effect of energy and investment literacy on electricity consumption. With respect to Blasch et al. (2017b), in this paper, we use a data set at the European level, a more comprehensive definition of energy-related financial literacy introduced by Blasch et al. (2021), which

distinguishes specific knowledge from cognitive ability and we analyze the association between these two types of literacy and the level of energy efficiency.

A model of electricity demand

For the specification of electricity demand, we should keep in mind that residential electricity consumption is driven by the demand for energy services such as lighting, cooked food, washed clothes, or hot water. Hence, the specification of the electricity model can be based on the household production theory. According to this theory, households use inputs to produce goods or services which are included in the households' utility function (Deaton and Muellbauer 1980). For the specification of an electricity demand model, we should consider a household that combines electricity and capital (fridges, washing machines, electronics, light bulbs, cooling systems, etc.) to produce energy services (Alberini and Filippini 2011). In this context, a household has to identify the optimal demand for capital and electricity that minimizes the cost to produce a predefined level of energy services. As illustrated by Flaig (1990) and Alberini and Filippini (2011), the optimal input demand functions are derived applying the duality theory and Shephard's Lemma from a theoretical point of view.² If a household is not using the optimal amount of electricity and/or capital to produce a predefined level of energy services, the production process is characterized by inefficiency in the use of both or one of these inputs.³

In this paper, we analyze the level of inefficiency in the use of electricity. Therefore, following Filippini and Hunt (2011), we estimate an electricity demand frontier function using econometric methods.⁴ This frontier function defines the minimum amount of electricity required to produce a predefined level of energy services, given the level of technology, input prices, and other factors. Therefore, a household that is not using the lowest quantity of electricity as defined by the

² See Chambers (1988) for a theoretical discussion on the derivation of the optimal input demand functions based on the production and duality theory using Shephard's Lemma.

³ Filippini and Hunt (2015) present a detailed theoretical discussion of the concept of energy efficiency based on the microeconomic theory of production.

⁴ See Filippini and Hunt (2011, 2015) for a detailed presentation of the concept of energy efficiency based on the production and duality theory and of the approaches that can be used to estimate the level of households' energy inefficiency.

frontier is characterized by inefficiency in the use of electricity. The ratio between the optimal and the observed use of electricity needed to produce an energy service is defined as the level of energy efficiency of a household. If this ratio is equal to one, then the level of energy efficiency is 100%; if the ratio is lower than one, then the household is said to be inefficient.

In our econometric analysis using micro-level data from Italian, Dutch, and Swiss households, we define the following electricity demand function based on the household production theory:

$$E_i = f(P_i^E, P_i^C, Y_i, H_i, ES_i, EFL_i, EF_i), \quad (1)$$

where E_i is the electricity consumption of household i , P_i^E is the price of electricity, P_i^C is the price of capital (i.e., the price of appliances and/or heating and cooling equipment), Y_i is income, H_i is a vector of house and household characteristics, ES_i is a vector of energy services consumed by a household, EFL_i represents an indicator of the level of energy-related financial literacy, and EF_i is the level of energy efficiency.

Due to missing information for part of the households, we cannot include the prices for electricity and capital as suggested by Equation (1). We address this limitation by introducing utility specific dummies.⁵ These variables capture, at least partially, the differences in the prices among the utilities as well as other institutional and regional differences that influence electricity demand.

In the empirical specification, vector H_i includes variables capturing the square meters of the dwelling, household size, and the age of the home. It further includes information on the presence of large and energy-intensive appliances and the number of light bulbs. We also control for ownership status and education. Furthermore, following Blasch et al. (2017c), we include in ES_i the energy services consumed, such as the number of meals cooked on electric stoves, the number of washing and drying cycles, the number of dishwasher cycles in a typical week, and the daily number of TV and computer hours.

As mentioned in the introduction of this paper, one of the goals of this study is to analyze the role of energy-related financial literacy on energy efficiency, and to distinguish between a pure

⁵ The empirical analysis is based on data from four utilities: one utility based in Italy, one utility based in the Netherlands, and two utilities based in Switzerland. In order to avoid multicollinearity, we introduce three dummy variables and exclude the one for the Dutch utility.

knowledge and a cognitive ability component. Following Blasch et al. (2021), the level of energy-related financial literacy (EFL_i) is measured using eight different questions. See the “Data” section for additional details.

Equation (1) additionally includes the variable EF_i , which is the unobserved level of electricity efficiency of the household that we want to estimate.

From an econometric point of view, we estimate the level of efficiency using the classical stochastic frontier function analysis (SFA) approach proposed by Aigner et al. (1977). This approach assumes that the level of inefficiency in the use of electricity can be represented by a one-sided non-negative term. Using a log-log functional form, Equation (1) can be written as:

$$\ln E_i = \alpha + X_i' \beta + (v_i + u_i). \quad (2)$$

where $\ln E_i$ is the natural logarithm of annual electricity consumption of household i and vector X_i' includes all explanatory variables. The continuous covariates in X_i' , such as the living area, are also ln-transformed.

As is usual in a stochastic frontier setting, the error term in Equation (2) is split into two independent parts. The first part, v_i , is a symmetric disturbance assumed to be normally distributed and capturing the random noise. The second part, u_i , is the one-sided measure of the level of energy inefficiency that can follow different distributions depending on the assumptions taken. In our econometric analysis, we assume that this term is half-normally distributed.⁶ Hence, the distributions of the two parts of the error term are formally defined as

$$v_i \sim N[0, \sigma_v^2], u_i \sim N^+[0, \sigma_u^2]$$

In this study, we are particularly interested to analyze the role of the level of energy-related financial literacy on the level of energy efficiency. Therefore, we use an adjusted version of the classical SFA proposed by Aigner et al. (1977) and suggested by Kumbhakar et al. (1991), where the level of inefficiency is

⁶ The half-normal distribution is standard in the estimation of production and cost frontier functions. Alternative distributions are the exponential, truncated normal, or the gamma distribution; see Kumbhakar and Lovell (2000), page 148, for a discussion. In a preliminary analysis, we also used the exponential distribution. The level of efficiency was slightly higher compared to the one obtained by imposing a half normal distribution but the ranking was similar.

heteroscedastic with the variance being a function of some explanatory variables z_i ⁷:

$$\sigma_{u,i}^2(z_i) = e^{\delta' z_i} \quad (3)$$

The exponential transformation is used in order to ensure that the variance is positive. δ is a vector of parameters to be estimated. As u_i is assumed to follow a half-normal distribution, its expected value is a function of its variance:

$$E(u_i) = \sigma \left(\frac{\phi(0)}{\Phi(0)} \right) = \sqrt{2/\pi} \cdot e^{\delta' z_i} = e^{\frac{1}{2} \ln(\frac{2}{\pi}) + \delta' z_i}, \quad (4)$$

where ϕ is the normal probability density function and Φ is the normal cumulative distribution function. Hence, we allow the mean efficiency to vary with z_i by making the σ_u^2 a function of these exogenous determinants. In this study, we use the following variables that do not have a direct impact on electricity consumption as determinants: education, ownership status, and energy-related financial literacy indices. This model can be estimated in a single step using a maximum likelihood approach.

Since only the composed error term is observed, the household's inefficiency is predicted by the conditional mean $\hat{u}_i = E[u_i | \varepsilon_i]$, where $\varepsilon_i = v_i + u_i$ (Jondrow et al. 1982). Energy efficiency for household i (EF_i) can then be calculated as:

$$EF_i = \frac{E_i^F}{E_i} = e^{-\hat{u}_i} \quad (5)$$

where E_i is the observed electricity consumption and E_i^F is the frontier demand of the i^{th} household. A value of one for the index EF_i indicates that a household is 100% efficient. A value lower than one means that a household is inefficient, i.e., it has a level of efficiency smaller than 100%. Consider that what we observe (E_i) is an ex-post level of consumption which combines technology and behavior. This measure differs from an ex-ante measure, which only considers technology. This distinction implies that expected savings might differ from actual savings, because the latter are influenced by both technology and behavioral change.

⁷ In the literature, we can find two approaches to analyze the role of a variable on the level of efficiency. The first approach consists of the introduction of the variable directly in the model. In this case, the variable may shift the frontier function. The second approach makes the mean and/or the variance parameters of u_i a function of a variable.

Data

Our data are drawn from a large-scale household survey, which has been conducted in three European countries (Italy, the Netherlands, and Switzerland). The survey was implemented in collaboration with four utilities.

Our final sample consists of 1375 households who participated in the survey.⁸ Information on energy services, dwelling characteristics, and socioeconomic attributes of the residents were collected. Additionally, we obtained data on energy-related financial literacy and on other psychological and behavioral factors. We merged these survey data with information on electricity consumption for 2016, provided by the utility companies. As we are only considering information for the year 2016, we are not able to exploit the advantages of panel data. In particular, we cannot apply the recently proposed econometric methods that allow to take into account the problems related to unobserved heterogeneity and to distinguish transient from persistent efficiency in an effective way.⁹

Generally, in household surveys implemented in such a manner, representativeness of the sample cannot be ensured ex-ante. Therefore, external validity is not easily established per se.

Table 5 in the Appendix provides descriptive statistics about some important characteristics for the three countries in the overall survey sample and compares it to the corresponding statistics at the national level. Across most characteristics, we do not find a severely large difference between the sample and national statistics. Thus, we can conclude that the sample selection bias is not too large overall. However, we find a larger share of respondents with tertiary education in our sample compared to the respective national statistics.

The variables used in the estimation of residential electricity demand are described below and summary statistics are presented in Table 1.

Table 6 in the appendix provides these statistics separately for each of the countries considered.

⁸ A total number of 4796 households originally responded to the survey. However, due to the missing values in both the dependent and the independent variables as well as some data cleaning measures, the final sample used in this paper is 1375.

⁹ See Filippini and Greene (2016) for an overview.

Electricity consumption

Residential electricity consumption in kWh—the dependent variable in our models (see the “A model of electricity demand” section)—can vary substantially across households. Values for the year 2016 in the final sample range from 344 to 36080 kWh, with a mean value of around 3826 kWh.¹⁰ As shown in Table 6, electricity consumption differs across countries too.¹¹ Generally, the electricity tariff structure is the same for all residential customers within utilities. Therefore, the price effect can be captured with utility-specific dummies in the models.

Dwelling characteristics

The first dwelling attribute is the floor area, measured in square meters (sqm). Over the entire sample, mean living area amounts to around 130 m², although Swiss and Dutch dwellings seem to be much larger than Italian ones on average. This may partly be explained by the higher fraction of single-family houses (*is_sfh*) in Switzerland and the Netherlands.¹² Three dummy variables indicate the period in which a house or apartment was built. We use four categories: before 1940, between 1940 and 1970, between 1971 and 2000, and after 2000 (reference).

¹⁰ We excluded from the sample households that exhibited a negative consumption or other unrealistic values, which could arise for several reasons. For instance, the consumption of people that moved in within 2016 might have not been measured for the entire year or the consumption of prosumers recorded by the utility does not reflect the true amount of electricity used. Households with unrealistic consumption values were identified through a comparison of the observed consumption and bottom-up defined minimum consumption values. These minima were calculated by summing up consumption values of the most efficient appliances on the market at the beginning of 2018 in case fridges or freezers exist in a dwelling. The same logic was applied to the number of cycles of dishwashers, washing machines, and tumble dryers. Additionally, 25 kWh per 10 square meter of living space was imposed for lighting, which is very conservative considering that engineering calculations for the most efficient houses in Switzerland (Minergie) use an unweighted value of around 35.7 kWh per square meter of living space (Cozza et al. 2019).

¹¹ Unfortunately, we do not have information on whether the households are prosumers; thus, we cannot control for self-produced renewable electricity. However, the share of households that invested in residential solar panels is relatively low in Italy (2.7%), the Netherlands (3.0%), and Germany (3.5%) (GfK Belgium consortium 2017). Unfortunately, there is no precise information for Switzerland.

¹² Single-family houses are semi-detached, detached as well as terraced houses.

Household composition and socioeconomic attributes

Our data set contains information on the number of people living regularly in the residence. The average household size is 2.64. For the analysis, we built four categories: single (*hs1*), two-person (*hs2*), and three-person (*hs3*) households, as well as apartments or houses that were occupied by more than three residents (reference category). We excluded participants that stated a household size of zero. In all countries considered, two-person households represent the most frequently observed category.

We further obtained data on the average number of full weeks within a year and the average number of days within a week a residence is completely unoccupied, e.g., due to work-related projects, vacations, or stays at a second home. We account for unoccupied residences within the weekly schedule by using two dummies that indicate an average absence of more than three (*dabs4p1*) or between 1 and 3 days (*dabs1to3*) a week. Moreover, we control for homes that are completely unoccupied for more than eight (*wabs8p1*) or between five and eight (*wabs5to8*) weeks within a year.

Finally, we account for level of education and income. The former is captured by two variables indicating whether a participant only attended mandatory schooling (*edu_mand*) or had tertiary education (*univ*). The share of respondents holding a university degree is quite high in both the Netherlands and Switzerland compared to Italy. Three dummy variables are used to control for the level of income: incomes below 1500 Euros per month, incomes between 1500 and 4500 Euros per month, and incomes between 4500 and 9000 Euros per month. Incomes higher than 9000 Euros per month are used as reference category.

Energy services and appliance stock

We have information on the consumption of several energy services. Number of warm meals cooked on an electric stove (*nmeals_el*) represents the average number of prepared lunches and dinners per week. This number seems to be particularly low for Italy, which is because most Italian households use gas for cooking. Swiss households primarily use electricity for meal preparation and the Dutch ones both energy sources. Number of entertainment services consumed in a typical day (*nentt*) is the sum of total hours of usual daily usage of all TVs and computers within the residence.

Table 1 Descriptive statistics

<i>N</i> =1375	Variable	Mean	Median	Std. Dev.	Min	Max
Electricity consumption [kWh]	kWhtotalEL	3837.81	2767	3896.65	343.76	36080
Income: less than 1500€	inc_1500	0.06	0	0.23	0	1
Income: 1501€–4500€	inc_1to4k	0.30	0	0.46	0	1
Income: 4501€–9000€	inc_4to9k	0.31	0	0.46	0	1
Household size	hs	2.64	2	1.21	1	6
Area (sqm)	sqm	131.61	120	65.56	30	400
Absence (yearly): 8 weeks and more	wabs8pl	0.04	0	0.21	0	1
Absence (weekly): 4 days and more	dabs4pl	0.03	0	0.17	0	1
Absence (yearly): 5–7 weeks	wabs5to8	0.08	0	0.27	0	1
Absence (weekly): 1–3 days	dabs1to3	0.15	0	0.36	0	1
2nd fridge	has_fr2	0.28	0	0.45	0	1
Freezer	has_freezer	0.53	1	0.50	0	1
Energy intensive appliance	eint_appl	0.19	0	0.39	0	1
Utility = AIL (Switzerland)	ail	0.14	0	0.35	0	1
Utility = SW (Switzerland)	sw	0.35	0	0.48	0	1
Utility = ENI (Italy)	eni	0.35	0	0.48	0	1
Number of meals (electric)	nmeals_el	4.33	2	4.81	0	14
Number of dishwasher cycles	ndishcy	3.44	3	2.51	0	8
Number of washing machine cycles	nwashing	3.59	3	2.68	0	15
Number of tumble dryer cycles	ndrying	1.20	0	2.05	0	15
Number of entertainment hours	nentt	7.99	6	6.24	0	48
Room temperature	rmtmp	20.18	20	1.75	15	25
Number of light bulbs	bulbtot	25.51	21	16.41	1	172
Space heating = electric	spheat_el	0.10	0	0.30	0	1
Water heating = electric	waheat_el	0.14	0	0.35	0	1
Air conditioner	ac	0.25	0	0.43	0	1
Building period: before 1940	blt1940	0.19	0	0.39	0	1
Building period: 1941–1970	blt1970	0.22	0	0.42	0	1
Building period: 1971–2000	blt2000	0.38	0	0.49	0	1
Single-family house	is_sfh	0.56	1	0.50	0	1
Owner	owner	0.75	1	0.43	0	1
Education: mandatory	edu_mand	0.22	0	0.42	0	1
Education: university	univ	0.54	1	0.50	0	1
Literacy: overall index	lit_index	4.69	5	1.72	0	8
Literacy: knowledge index	lit_knowledge	2.45	2	1.32	0	5
Literacy: cognitive index	lit_cogn_abil	2.24	2	0.74	0	3

At around 4.5 times per week on average, dishwashers (ndishwcy) are most frequently used in the Netherlands, compared to about 3.5 and 3 times per week in Switzerland and Italy. Dutch and Italian participants use the washing machine for 4 cycles per week on average (nwashing), while Swiss ones only do so 3 times per week

on average. Respondents only used dryers (ndryin) about once a week on average. In our estimations, we sum up the number of washing and drying cycles to one variable. The average indoor room temperature is slightly higher than 20 degrees Celsius but substantially higher in Switzerland than in both Italy and the Netherlands.

The average number of light bulbs (bulbtot) installed ranges between 20 and 30 across the countries considered. Dichotomous variables capture whether a household owns a second fridge (has_fr2), a separate freezer (has_freezer), an air conditioner (ac), or a special energy intensive appliance (eint_appl) like a sauna, swimming pool, or home theatre system. Other binary variables control for the presence of an electric space (spheat_el) or water (waheat_el) heating system, as those systems increase electricity consumption substantially compared to dwellings that use oil or gas-based heating.

Energy-related financial literacy

The survey included eight questions that account for several dimensions of energy-related financial literacy. Five of these eight questions tried to assess the level of knowledge related to electricity price, the electricity consumption of some appliances, and the concept of risk diversification. The remaining three questions were structured to collect information on the level of cognitive skills of the households in performing an investment analysis and computing the lifetime cost of an appliance. In particular, two out of these three questions ask respondents to make calculations considering the inflation rate and the concept of compound interest rate, while the third question targets computation of the lifetime cost of an appliance. We provide a description of the questions used to compute the literacy variables in the “Appendix” section. Based on the number of correct answers to the different questions, we compute three indices of energy-related financial literacy.¹³ We construct a general index of energy-related financial literacy (lit_index) based on all eight questions available, which takes values from 0 to 8. We also split the general index into two sub-indices and compute one index varying from 0 to 5 that should reflect the level of energy-related knowledge (lit_knowledge) and a second index varying from 0 to 3 that should represent the level of cognitive abilities of the households in doing an investment calculation (lit_cogn_abil). We think that this distinction is interesting because it allows us to separate the role of knowledge from the role of cognitive ability with respect to the level of efficiency.

¹³ In computing the literacy indices, we made the assumption that each literacy question has the same weight. Therefore, a correct answer receives one point and the indices are computed by summing up the number of correct answers.

Results

The electricity demand frontier model in Equation (2) has been estimated using the maximum likelihood estimator for cross-sectional data implemented in Stata by Kumbhakar et al. (2015). Table 2 displays the regression results for two specifications. In the model presented in column (1), we use the general index of energy-related financial literacy, while in column (2), we use the two specific literacy sub-indices previously described. In general, a majority of the estimated coefficients show the expected signs and are statistically significant.¹⁴

Even though the income dummies themselves are not significant, several explanatory variables that are correlated with income, such as the area of the home and the presence of specific appliances, are positive and strongly significant. Moreover, the household size seems to play an important role, as households having one or two members use less electricity than households with four or more members, while there is no significant difference between households with three inhabitants and the reference category. The area of the house and the indicator of whether the dwelling is a single-family house are positively and significantly correlated with the consumption of electricity. In addition, the coefficients on the availability of electric space heating, water heating, a second fridge, or a separate freezer are likewise positive and significant. Moreover, the ownership of an air conditioner or special energy-intensive appliances (like sauna, solarium, etc.) and the total number of light bulbs have positive and significant coefficients.

Standard errors are reported in parentheses. */**/** indicate statistical significance at the 10, 5, and 1 percent level, respectively

Most energy service-related variables, such as the number of washing and drying cycles, the number of dishwasher cycles and indoor temperature, or the number of TV and computer hours, are associated positively and significantly with electricity consumption.

The dummies indicating longer absence—except absences of 4 days and more per week—seem to play an important role too, as they are negatively and

¹⁴ In order to check the robustness of the results, we also estimate Equation (2) with the following modifications: (a) use of the log of the average electricity consumption per occupant as a dependent variable; (b) excluding energy services, (c) country-specific models (Italy and Switzerland) although the sample size is relatively small, and d) using regional/country dummies instead of utility indicators. The main results are confirmed.

Table 2 Estimation results

		(1)	(2)	
Frontier	Income: below 1500€	-0.016 (0.062)	-0.030 (0.062)	
	Income: 1501–4500€	-0.049 (0.037)	-0.048 (0.037)	
	Income: 4501–9000€	-0.018 (0.031)	-0.015 (0.031)	
	Household size: 1	-0.253*** (0.048)	-0.253*** (0.047)	
	Household size: 2	-0.085*** (0.033)	-0.089*** (0.033)	
	Household size: 3	-0.028 (0.038)	-0.033 (0.037)	
	ln(area)	0.232*** (0.037)	0.237*** (0.037)	
	Second fridge	0.137*** (0.029)	0.131*** (0.029)	
	Freezer	0.138*** (0.028)	0.139*** (0.027)	
	E-intensive appliance	0.109*** (0.032)	0.102*** (0.031)	
	Utility = AIL	0.446*** (0.06)	0.448*** (0.060)	
	Utility = SW	0.264*** (0.052)	0.261*** (0.052)	
	Utility = ENI	0.106** (0.047)	0.109** (0.047)	
	ln(#meals)	0.025 (0.018)	0.025 (0.018)	
	ln(#dishw cycles)	0.131*** (0.020)	0.130*** (0.020)	
	ln(#washing cycles)	0.145*** (0.020)	0.147*** (0.020)	
	ln(#entert hours)	0.136*** (0.021)	0.135*** (0.021)	
	ln(room temperature)	0.251 (0.156)	0.260* (0.155)	
	ln(#light bulbs)	0.042 (0.026)	0.047* (0.026)	
	El space heating	0.347*** (0.049)	0.348*** (0.049)	
	El water heating	0.479*** (0.041)	0.479*** (0.041)	
	Air conditioner	0.106*** (0.034)	0.108*** (0.034)	
	Single family house	0.114*** (0.032)	0.107*** (0.031)	
	Building period: <1940	0.061 (0.040)	0.056 (0.040)	
	Buidling period: 1940–1970	0.037 (0.038)	0.028 (0.038)	
	Building period: 1971–2000	0.020 (0.034)	0.016 (0.033)	
	Absence: 5–8 weeks/year	-0.106** (0.045)	-0.109** (0.045)	
	Absence: >8 weeks/year	-0.129** (0.060)	-0.129** (0.060)	
	Absence: 1–3 days/week	-0.103*** (0.035)	-0.105*** (0.035)	
	Absence: >3 days/week	-0.033 (0.074)	-0.021 (0.073)	
	Constant	4.634*** (0.495)	4.569*** (0.492)	
	σ_u^2	Educ: basic	-0.183 (0.297)	-0.261 (0.290)
		Educ: university	-0.140 (0.255)	-0.159 (0.240)
Owner		0.510* (0.309)	0.490* (0.283)	
ln(lit_index)		-0.469* (0.281)		
ln(lit_knowledge)			0.283 (0.228)	
ln(lit_cogn_abil)			-1.139*** (0.329)	
Constant		-1.984*** (0.605)	-1.688*** (0.494)	
σ_v^2	Constant	-1.825*** (0.091)	-1.853*** (0.081)	
	Log-likelihood	-814.740	-809.363	
p value	0.000	0.000		
N	1375	1375		

significantly correlated with electricity consumption. The dummies for different building periods of the dwellings are insignificant across all four models.

In the second part of Table 2, we report the coefficients of the determinants of inefficiency. As previously mentioned, we select the following determinants: education, ownership status, and energy-related financial literacy indices. The coefficients of the educational dummies are not significant. Respondents owning their homes tend to exhibit higher inefficiency. This may indicate that some renters in the sample do not pay for their entire energy consumption (e.g., because of shared facilities such as laundry rooms that run on separate meters).

As we are most interested in the effect of the level of energy-related financial literacy on the energy efficiency, we now turn our attention to the sign and significance of this determinant in our two models. As shown in columns (1) and (2), the general index of energy-related financial literacy and the index of cognitive abilities of the households in doing an investment calculation play a significant role in explaining the level of energy inefficiency. Respondents achieving a higher energy-related financial literacy score in general or attaining a higher score in the cognitive abilities questions have lower inefficiency. On the contrary, the level of energy-related knowledge does not seem to be significantly correlated with the level of energy inefficiency.

The findings concerning the energy-related knowledge may explain why informational interventions are not always effective in improving energy efficiency. For example, some studies find that providing information on savings or energy cost for appliances and vehicles did not influence driving behavior or investment in energy-efficient appliances and vehicles (Allcott and Knittel 2019; Allcott and Sweeney 2016; Allcott and Taubinsky 2015; Kallbekken et al. 2013; Tertoolen et al. 1998). While bounded rationality seems to be a strong barrier to energy efficiency, imperfect information and limited knowledge are possibly only minimal barriers. The fact that the cognitive abilities play a more salient role than the energy-related knowledge is indicative of the importance of removing barriers to making investment decisions for improving energy efficiency in the residential sector.

Standard errors are reported in parentheses and were obtained by bootstrapping using 1000 replications. */**/** indicate statistical significance at the 10, 5, and 1 percent level, respectively

The estimated coefficients of the inefficiency term only indicate the direction of the effect but not the

determinants' marginal effects on inefficiency. In case u_i is assumed to follow a half-normal distribution and the parameterization is given by Equation (3), the marginal effect of the k^{th} variable of the z_i vector can be calculated by:

$$\frac{\partial E(u_i)}{\partial z_k} = \delta_k \frac{\sigma_{u,i}}{2} \left(\frac{\phi(0)}{\Phi(0)} \right) = \delta_k \sigma_{u,i} \phi(0). \quad (6)$$

The marginal effects on the unconditional expected value of the inefficiency term $E(u_i)$ for the determinants of interest, i.e., the various indices of energy-related financial literacy are given in Table 3. In particular, the level of energy inefficiency is reduced, on average, by around 0.06% for every 1 percentage increase in the overall literacy index and by around 0.14% for every 1 percentage increase in cognitive abilities.

Finally, the results of the econometric estimations in Table 2 can be used to estimate the efficiency levels as described in Equation (5). Table 4 provides descriptive statistics on the energy efficiency levels for the households in our sample and country-level descriptive statistics. The table shows that in both models, the estimated mean efficiency is around 80%. Hence, European households could save roughly 20% of their electricity usage by correcting inefficiencies. We also provide the estimated efficiency levels across countries: the means of the efficiency levels do not differ significantly, and the standard deviation, as well as the maximum level of efficiency, is similar across countries. However, the minimum levels (around 45–50% for Switzerland, 35–40% for Italy, and 40–50% for the Netherlands) vary across countries.

Conclusions

This paper provides an empirical analysis on the level of efficiency in the use of electricity for a sample of households in three different European countries. This analysis draws on micro level data on electricity consumption, energy services, and other household-level information

Table 3 Marginal effects of energy-related financial literacy variables

	(01)	(02)
ln(lit_index)	-0.055** (0.027)	
ln(lit_Knowledge)		0.035 (0.031)
ln(lit_Cogn abil)		-0.139*** (0.042)

Table 4 Estimated efficiency levels

		Mean	Median	SD	Min	Max
Overall	(1)	0.807	0.816	0.058	0.398	0.919
	(2)	0.800	0.813	0.066	0.335	0.918
CH	(1)	0.815	0.824	0.055	0.455	0.919
	(2)	0.807	0.821	0.063	0.495	0.918
IT	(1)	0.795	0.799	0.060	0.398	0.915
	(2)	0.790	0.796	0.062	0.335	0.915
NL	(1)	0.808	0.820	0.055	0.476	0.912
	(2)	0.801	0.819	0.066	0.385	0.912

and applies them to a stochastic frontier analysis. Moreover, we link energy efficiency to energy-related financial literacy.

We apply two electricity demand frontier specifications that differ in terms of the exogenous determinants of the inefficiency term. All models control for dwelling characteristics, household composition, the amount of energy services consumed, and the ownership of certain special appliances and other socioeconomic variables. The two econometric models yield similar assessments of the current level of efficiency in the use of electricity of the households. The mean values of the individual estimates of the energy efficiency are similar and suggest that the efficiency is around 80% in our sample. Moreover, the overall level of energy-related financial literacy seems to play an important role in explaining the level of efficiency. Furthermore, we split the index of energy-related financial literacy into two parts: energy-related knowledge and cognitive abilities of the households in doing an investment calculation. The cognitive abilities in doing an investment calculation seem to play a more important role than the energy-related knowledge in explaining the level of efficiency in the use of electricity. More specifically, respondents having stronger cognitive abilities are associated with a lower level of inefficiency in electricity consumption. This suggests that removing cognitive barriers to making investment decisions is important for improving energy efficiency in the residential sector.

From a policy point of view, the empirical results presented in this paper can play an important role. First, the results clearly indicate that there is considerable potential for saving electricity in the residential sector and thus curbing the associated CO₂-emissions in the three sampled European countries. The level of inefficiency is partially due to consumers that do not adopt energy-efficient appliances or do not use their appliances in an optimal way.

This conclusion is especially relevant, as EU countries agreed on an energy efficiency target for 2030 of 32.5% within the new Energy Efficiency Directive. Furthermore, improvements in energy efficiency represent a crucial strategy to meet the long-term 2050 greenhouse gas reductions target of the European Union. Second, the energy saving potential is relatively homogeneous in the residential sector of the European countries considered in this analysis. Third, the European Union might consider promoting the level of energy-related financial literacy through educational programs, to help households to improve their abilities in making investment calculations for investments in energy efficiency. Another interesting instrument could be the promotion of life-time cost calculators for appliances, which make investment calculations easier for households. The impact of these two instruments is well documented in Blasch et al. (2017a). Of course, bounded rationality among consumers might also justify the use of energy efficiency regulations and standards on electrical appliances, which however would need to be verified in the individual case.

This paper has some limitations. First, the model imposes a zero rebound effect. However, the savings from the adoption of more energy-efficient appliances might be partially washed out if consumers react by using these appliances in a less efficient way. This phenomenon occurs because the cost per unit of energy services decreases when the production of these energy services becomes more efficient. Second, we could not control for the electricity prices as suggested by the model of electricity demand. However, given that the estimation of energy price elasticity was beyond the scope of this paper, we think that the use of utility dummies that absorb the regional variation of the prices is a valid approach for the purpose of our analysis. Finally, we measured the level of efficiency only in the use of electricity, but we are aware that households make use of different sources of energy, including gas and oil.

Acknowledgment We acknowledge financial support from the European Union's Horizon 2020 research and innovation program under grant agreement No. 723791 - project PENNY "Psychological, social and financial barriers to energy efficiency", and financial support from the Swiss State Secretariat for Education, Research and Innovation (SERI) under contract number 16.0087. This research is also part of the activities of SCCER CREST, which is financially supported by the Swiss Commission for Technology and Innovation (CTI) / Innosuisse.

Funding Open Access funding provided by ETH Zurich.

Appendix. Questions used to compute the energy-related financial literacy indices

No	Survey question	Interpretation	Index
1	How much do you think 1 Kilowatt hour (kWh) of electricity currently costs in “target country” (on average after taxes)?	Correct answers take the value of 1; 0 otherwise.	lit_knowledge
2	How much do you think it costs in terms of electricity to run a desktop PC for 1 hour?	Correct answers take the value of 1; 0 otherwise.	lit_knowledge
3	How much do you think it costs in terms of electricity to run a washing machine (load of 5 kg at 60 °C)?	Correct answers take the value of 1; 0 otherwise.	lit_knowledge
4	How much do you think is the energy saving associated with using a LED light bulb instead of a conventional halogen bulb (with the same brightness)?	Correct answers take the value of 1; 0 otherwise.	lit_knowledge
5	Suppose you had 100 € (CHF) in a savings account and the interest rate was 2% per year. After 5 years, how much do you think you would have in the account if you left the money to grow?	Correct answers take the value of 1; 0 otherwise.	lit_cogn_abil
6	Imagine that the interest rate on your savings account was 1% per year and inflation was 2% per year. After 1 year, how much would you be able to buy with the money in this account?	Correct answers take the value of 1; 0 otherwise.	lit_cogn_abil
7	Please tell me whether this statement is true or false. “Buying a single company’s stock usually provides a safer return than buying stocks of several companies.”	Correct answers take the value of 1; 0 otherwise.	lit_knowledge
8	Suppose you own your home. Your fridge breaks down and you need to replace it. As a replacement, you can choose between two alternatives that are identical in terms of design, capacity, and quality of the cooling system. Fridge A sells for 400 € (CHF) and consumes electricity for the amount of 300 kWh per year. Fridge B has a retail price of 500 € (CHF) and consumes electricity for the amount of 280 kWh per year. Assume the average cost of energy is 0.2 € (CHF) per kWh, the two models have both a lifespan of 15 years and that you would get a return of 0 percent from any alternative investment of your money. Which choice of purchase minimizes the total costs of the fridge over its lifespan?	Correct answers take the value of 1; 0 otherwise.	lit_cogn_abil

Table 5 Selected household characteristics in the sample and in the national statistics

	Italy		Netherlands		Switzerland	
	Sample (%)	Statistic	Sample (%)	Statistic	Sample (%)	Statistic
Residence characteristic						
Single-family house	43.63	47.20	73.21	76.50	51.62	37.00
Apartment in multi-family house	56.37	52.20	26.79	19.90	48.38	60.10
Ownership status						
Owned	84.68	72.90	73.21	67.80	58.59	44.50
Gross monthly household income (in Euro/CHF)						
Below 1500	15.12		6.16		1.01	
1501 to 4500	50.93		47.70		10.28	
4501 to 6000	8.95		19.18		11.96	
6001 to 9000	5.74		15.38		28.04	
9001 to 12,000 CHF	1.75		5.73		22.46	
More than 12,000 CHF	17.51		5.85		26.26	
Household disposable income		4417.95		4614.34		6993.87
Education of respondent						
Lower secondary education and less	11.21	41.60	5.91	27.90	2.11	18.20
Upper secondary/vocational	54.24	42.70	24.09	41.10	40.42	46.30
Tertiary	34.55	15.70	70.01	31.00	57.46	35.40

We report the statistics at the national level as computed by Eurostat (residence characteristics, household type and education) and by OECD (household income)

Table 6 Descriptive statistics by country

	Switzerland (N=667)						Italy (N=485)						Netherlands (N=223)					
	Mean	Median	SD	Min	Max		Mean	Median	SD	Min	Max		Mean	Median	SD	Min	Max	
kWhtotalEL	5032.98	3255	5089.96	383	36080		2538.78	2355.092	1374.41	343.7566	11438.32		3088.24	2706	1895.25	579	16331	
inc_1500	0.01	0	0.09	0	1		0.14	0	0.35	0	1		0.02	0	0.15	0	1	
inc_1to4k	0.09	0	0.28	0	1		0.54	1	0.50	0	1		0.40	0	0.49	0	1	
inc_4to9k	0.40	0	0.49	0	1		0.13	0	0.33	0	1		0.43	0	0.50	0	1	
hs	2.60	2	1.24	1	6		2.65	2	1.15	1	6		2.73	2	1.21	1	6	
sqm	140.54	120	65.02	30	400		108.43	100	50.77	30	400		155.34	140	79.50	40	400	
wabs8pl	0.03	0	0.16	0	1		0.05	0	0.22	0	1		0.09	0	0.28	0	1	
dabs4pl	0.01	0	0.09	0	1		0.06	0	0.23	0	1		0.03	0	0.16	0	1	
wabs5to8	0.10	0	0.30	0	1		0.07	0	0.26	0	1		0.05	0	0.23	0	1	
dabs1to3	0.12	0	0.33	0	1		0.22	0	0.42	0	1		0.10	0	0.30	0	1	
has_fr2	0.25	0	0.43	0	1		0.20	0	0.40	0	1		0.54	1	0.50	0	1	
has_freezer	0.66	1	0.47	0	1		0.28	0	0.45	0	1		0.65	1	0.48	0	1	
eint_appl	0.21	0	0.41	0	1		0.18	0	0.38	0	1		0.15	0	0.36	0	1	
ail	0.28	0	0.45	0	1		0.00	0	0.00	0	0		0.00	0	0.00	0	0	
sw	0.72	1	0.45	0	1		0.00	0	0.00	0	0		0.00	0	0.00	0	0	
eni	0.00	0	0.00	0	0		1.00	1	0.00	1	1		0.00	0	0.00	0	0	
nmeals_el	7.85	8	3.91	0	14		0.55	0	2.35	0	14		2.00	0	3.37	0	11	
ndishcy	3.56	3	2.32	0	8		2.85	3	2.63	0	8		4.35	5	2.50	0	8	
nwashing	3.11	3	2.60	0	15		4.11	4	2.73	0	15		3.92	4	2.53	0	12	
ndrying	1.27	0	1.93	0	15		0.71	0	1.94	0	15		2.08	1	2.30	0	10	
nennt	6.89	6	5.78	0	48		8.60	8	6.20	0	46		9.96	8	6.98	2	37	
rmtmp	20.97	21	1.47	15	25		19.44	20	1.77	15	25		19.43	20	1.40	15	24	
bulbot	28.30	24	18.54	1	172		20.41	18	11.99	4	96		28.27	25	15.31	4	115	
spheat_el	0.16	0	0.37	0	1		0.03	0	0.17	0	1		0.07	0	0.25	0	1	
waheat_el	0.22	0	0.42	0	1		0.07	0	0.26	0	1		0.04	0	0.19	0	1	
ac	0.07	0	0.26	0	1		0.56	1	0.50	0	1		0.09	0	0.29	0	1	
blt1940	0.21	0	0.41	0	1		0.12	0	0.32	0	1		0.26	0	0.44	0	1	
blt1970	0.22	0	0.41	0	1		0.27	0	0.44	0	1		0.15	0	0.36	0	1	
blt2000	0.35	0	0.48	0	1		0.42	0	0.49	0	1		0.40	0	0.49	0	1	
is_sfh	0.55	1	0.50	0	1		0.42	0	0.49	0	1		0.88	1	0.32	0	1	

Table 6 (continued)

	Switzerland (N=667)						Italy (N=485)						Netherlands (N=223)					
	Mean	Median	SD	Min	Max		Mean	Median	SD	Min	Max		Mean	Median	SD	Min	Max	
owner	0.64	1	0.48	0	1		0.85	1	0.35	0	1		0.88	1	0.33	0	1	
edu_mand	0.29	0	0.46	0	1		0.15	0	0.36	0	1		0.18	0	0.39	0	1	
univ	0.60	1	0.49	0	1		0.36	0	0.48	0	1		0.75	1	0.43	0	1	
lit_index	5.02	5	1.67	0	8		4.00	4	1.57	0	8		5.19	5	1.70	0	8	
lit_knowledge	2.70	3	1.33	0	5		1.96	2	1.19	0	5		2.75	3	1.28	0	5	
lit_cogn_abil	2.32	2	0.69	0	3		2.04	2	0.76	0	3		2.43	3	0.74	0	3	

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