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The impact of lifestyle and attitudes on residential firewood demand in Norway

Shuling Chen Lillemo [a,*], Bente Halvorsen [a,b]

[a] Department of Economics and Resource Management, Norwegian University of Life Science, P.O. Box 5003, N-1432 Aas, Norway
[b] Statistics Norway, P.O. Box 8131 Dep, N-0033 Oslo, Norway

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ABSTRACT

In this paper, we analyze the determinants of the demand for firewood by Norwegian households, focusing on intrinsic factors such as lifestyle and environmental attitudes, along with household socioeconomic characteristics. The data are from the Norwegian Consumer Expenditure Survey and a supplementary questionnaire on energy consumption and lifestyle. We apply a zero-inflated negative binomial model to correct for over-dispersion and the excessive number of zeros in the data. The results indicate that an urban lifestyle and concerns for comfort are negatively associated with firewood demand. In addition, price has a strong negative effect on demand. However, the most important determinants of household firewood demand are the characteristics of the household residence, including location, and household characteristics such as age and income.

1. Introduction

Norwegians have a long tradition of using firewood to heat their residences, and historically firewood was the dominant source of heating for most households. However, in the last decades the use of other energy sources has increased, and electricity is now the main heating source for 70% of Norwegian households [1]. While firewood remains the second most important source of heating in Norwegian households, its share of total energy use has fallen significantly, and now accounts for less than 20% of household energy consumption [2]. Nonetheless, biomass energy resources remain abundant in Norway [3,4], and as a renewable energy source, biomass is expected to play a significant role in both reducing greenhouse gas emissions [5] and combating global warming [6]. The consumption of biomass, such as firewood and pellets, is encouraged by the Norwegian government as a means of reducing the dependency on electricity, develop rural areas and combating climate change [7].

To achieve the policy aim of increased use of biomass for residential heating, we need to better understand the factors affecting firewood demand. Economic costs are important when households make choices regarding energy use, but price and heating cost are not the only determinants [8,9]. Haas et al. [10], for instance, argue that behavior pattern plays an important role in explaining total energy consumption for space heating by private homeowners. In general, what we choose to buy or consume also reflects who we are, including our lifestyle and attitudes or preferences about time, comfort, and environmental concerns [11]. By lifestyles we mean a set

* Corresponding author. Tel.: +47 45066216; fax: +47 64965701.
E-mail addresses: shulic@umb.no (S.C. Lillemo), bente.halvorsen@umb.no (B. Halvorsen).
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of basic attitudes, values, and patterns of behavior that are common to a social group. In this study, we represent lifestyles in terms of consumption patterns and attitudes. Furthermore, the characteristics of the household and residence are also the key factors in explaining the total firewood demand for heating.

Several studies discuss the determinants of household energy consumption (or expenditures) for heating purposes in Europe [12–20]. Although most of these studies include household socioeconomic factors in explaining the demand, few consider household attitudes, lifestyle, or other identity statements. Furthermore, most of these studies focus on the demand for electricity, and very few include other energy sources in the analysis [12]. Even fewer specifically analyze the attitude or perception determinants of household firewood demand. As an exception, Nyrud et al. [17] adopts a structural equation modeling approach to examine the use of new and more energy efficient woodstoves in Oslo. They concluded that the key factors determining the inclination of households to invest in the new woodstove were economic benefits, heating performance, the perceived time and effort in operating the stove, and the environmental effects of heating, as well as the perceived subjective norm. However, in their study, they did not model the actual demand for or expenditure on firewood. Actual firewood demand is rarely being studied, partly because of the complexities in measuring and estimating firewood consumption [21].

Analyzing firewood consumption is generally complicated for a number of reasons. First, most households have problems accurately reporting their consumption of firewood as the feedstock may come from either purchases, gifts, or their own gathering and chopping. Fortunately, our data have information on all of these sources of firewood. In addition, the customary way of measuring firewood in cords (3.62 m^3 of well-stacked wood) is unfamiliar to most users, and firewood is instead often purchased in sacks of various sizes or on pallets. Thus, reporting the exact amount of firewood acquired by the household is difficult.

Second, in a representative sample, there will be many zero observations for firewood consumption, and this makes estimation difficult. Zero observations may arise for two main reasons. First, the household will not acquire firewood if it does not have a woodstove or fireplace in its residence (i.e. no opportunity for consumption). This group will never acquire firewood (hereafter referred to as “always zero”). Alternatively, the household may choose not to acquire firewood because it is either consuming firewood from an existing stock or because it chooses not to consume firewood at all (i.e. a corner solution). This second group of consumers may choose to acquire firewood depending on the price, income, or other factors.

The main aim of this paper is to estimate a model of firewood demand and to identify the characteristics of firewood use. Hopefully it can contribute to the development of improved policy measures aimed at increasing the utilization of solid biomass consumption in Norwegian households. The estimation draws on a unique data set, which includes data on both firewood consumption and household attitudes and lifestyles. By studying household consumption decisions, we can see how differences in lifestyle factors affect decisions on how much firewood to consume.

2. Modeling household lifestyle and energy use

Classical consumer theory assumes that consumers choose the consumption bundle that maximizes their utility subject to a budget constraint [22], such that consumption is a function of income and prices for a given set of preferences. Consumers often choose certain products, services, and activities because they are associated with certain lifestyle patterns or social identification [23]. In the current analysis, lifestyle refers to a pattern of consumption reflecting individual choices of how we spend time and money: that is, who we are and what we do [11]. We follow Akerlof and Kranton [24] and specify a demand function in which we can include, among other things, assumptions concerning attitude and identity statements. We assume the decision maker’s utility function is given by:

$$U_i = U_i(a_i, I_i(a_i, k_i, l_i)) \quad (1)$$

where a_i is the action made by household i, in our case, the action of using firewood for heating. Note that the household is the observation unit. The variable I_i represents identity, which describes the household’s lifestyle patterns and attitudes, and thereby reflects attitudes about time, comfort, cost, and the environment, etc. The variables k_i and l_i respectively represent the characteristics and lifestyle of household i. Note that the identity statements depend on the chosen actions, lifestyle, and characteristics of consumers. In this model, the consumers derive utility, not only through the consumption of goods or services, but also from the opportunity to express their identity. Household i is then assumed to select that action a_i and lifestyle l_i, which maximizes their utility U_i. We assume that all household preferences are given.

We expect household lifestyles and attitudes to be important determinants of firewood consumption. This is because relying on firewood for heating the residence requires considerable time and effort. First, the household has to acquire the firewood, by purchasing and/or chopping and piling the wood. This is hard and time-consuming labor. Second, heating with firewood also requires daily labor to feed the stove. Third, cleaning the ashes away after wood burning is also tedious work for most people. Finally, lighting the stove and keeping the fire burning at the desired intensity takes skill, particularly with older woodstoves. Thus, it takes a serious commitment to use firewood to heat the residence on a daily basis, especially when you take into consideration the comparative simplicity of operating electric panel ovens and heat pumps. Thus, we expect households that are traditional in their lifestyle and spend much time in the residence to have the highest firewood demand.

3. The data

In this analysis, we apply a unique data set containing information on household energy consumption, characteristics of the household and the household residence, as well as information about attitudes and lifestyle. The main source of data is the Norwegian Survey of Consumer Expenditure (NSCE) conducted by Statistics Norway. The NSCE contains information concerning household expenditures on a wide range of goods, including firewood.

In both the 1997 and 1998 surveys, a supplementary questionnaire was included containing questions about household attitudes towards energy consumption, as well as questions concerning lifestyle and environmental concerns [25].

Unfortunately, the NSCE did not include this supplement in any subsequent years, so we do not have access to more recent data. Conducting a similar survey by collecting firewood consumption information with the same accuracy as in the NSCE would be very costly, and as far as we are aware, Statistics Norway has no plans for repeating the survey in the near future. Even though heating practice has changed somewhat during the last 15 years, firewood remains the second most used energy source in Norwegian households, and we expect that the driving forces underlying household firewood consumption have not changed substantially.

The sample in the NSCE is drawn randomly from the Norwegian population, and each drawn individual is attached to a family. Of the original sample of 2000 households, 1361 households responded to both the main survey and the supplementary energy questionnaire. Of these, 1155 observations remain after deletions because of missing values and errors in the data. The main NSCE survey contains information about, among other things, the amount of firewood acquired (purchased, chopped by the consumer, or received as a gift) during the last 12 months, measured in volumes (sacks). The survey also contains information about the characteristics of the household and residence. The individual in charge of purchases in the household answered both the main survey and the supplementary questionnaire on energy.

To measure the respondent's attitudes towards the environment and comfort, time spent outside the residence, and the degree of urban lifestyle (frequency of going to theaters, cinema, eating out, etc.), We create several indices based on the responses to the supplementary questionnaire on these questions. This questionnaire also provides information about whether the household engaged in any form of electricity-saving behavior. We treat this variable as an indication of attitudes and lifestyle, as pronounced savings behavior is an indication of a desire to save energy.

Table 1 details the mean values of the main variables used in this analysis. In order to see how the variables vary across households with different lifestyles, we calculate the means for six different groups of households. Column 1 includes the means for all households in the sample. Column 2 reports the means for households engaged in electricity-saving behavior and Column 3 tables the means of households with a high score on the comfort index (scores greater than three). Columns 4–6 report the means of households in the upper quartiles of the distributions of urban living index, the time out of the residence index and the environmental concern indexes respectively.

As shown in Table 1, households living an urban lifestyle use relatively less firewood and households that are more environmentally conscious use relatively more firewood than other households. Environmentally conscious households also have a lower likelihood of a zero observation for firewood consumption. Households with an urban lifestyle face the

Table 1 – Mean values for the main variables used in the analysis.

Variable	All	Electricity savers	Comfort seekers	Urban lifestyle	Often outside residence	Concerned with the environment
Total acquired firewood consumed (sacks)	36.30	33.17	33.06	24.93	33.13	40.46
Zero firewood consumption (0, 1)	0.41	0.41	0.42	0.48	0.40	0.36
Price of firewood (Euro)	2.38	2.30	2.40	2.74	2.47	2.45
Involved in electricity-saving behavior (0, 1)	0.74	1.00	0.70	0.68	0.71	0.80
Urban living style index (1,…, 5)	1.96	1.94	1.99	2.87	2.11	1.90
Comfort concern index (1,…, 5)	3.41	3.40	4.32	3.50	3.52	3.29
Time spent outside residence (hours per week)	19.76	20.23	20.13	25.82	39.37	19.43
Environmental concern index (1,…, 5)	3.16	3.17	3.13	3.21	3.15	4.20
Living in detached house (0, 1)	0.62	0.62	0.63	0.55	0.61	0.57
Living in farmhouse (0, 1)	0.09	0.09	0.08	0.05	0.05	0.14
Living in apartment (0, 1)	0.10	0.11	0.10	0.19	0.14	0.14
Size of dwelling (m^2)	134.99	135.38	136.92	130.79	126.03	125.81
Time living in current residence (years)	13.60	14.38	13.49	10.19	11.93	16.02
Living in cities (0, 1)	0.21	0.23	0.22	0.28	0.24	0.23
Owning cottage in the mountains (0, 1)	0.12	0.12	0.13	0.11	0.13	0.12
Household yearly income after tax (125 Euro)	214.14	206.49	218.03	238.97	198.23	210.76
Education level (1,…, 8)	4.19	4.16	4.21	4.48	4.03	3.90
Age of household (years)	45.33	46.27	45.22	40.56	42.86	49.22
Number of observations	1361	503	757	202	248	322

1 Euro = 8 NOK.
Data source: Statistics Norway Survey of Consumer Expenditure for 1997–1998 with supplementary questionnaire on energy and lifestyle [25].

highest mean prices for firewood, which may in part explain their lower consumption.

The next group of variables is the score on the lifestyle and attitude indexes. We can see that households living an urban lifestyle are considerably less involved in electricity-saving behavior, particularly when compared with the group of environmentally concerned households. In turn, environmentally concerned households score lower on the comfort index compared with other households. Households with an urban lifestyle spend more time outside the residence than other groups. Given "time spent outside residence" also includes outdoor activities such as camping and hiking, this does not necessarily coincide with an urban lifestyle.

With respect to the choice of residence, two particular groups stand out: households living an urban lifestyle and environmentally concerned households. Households living an urban lifestyle are more likely to reside in apartments and less likely to live in detached houses or farmhouses than the average household. Compared with the average household, they also reside in smaller residences in the city and have lived in their current residence for a shorter period. In contrast, environmentally concerned households are more likely to live in either an apartment house or a farmhouse. Compared with the average household, they also typically reside in smaller residences and have lived there for a longer period.

With respect to household characteristics, households living an urban lifestyle have a relatively higher mean income, a higher level of education, and are younger. In contrast, environmentally concerned households are relatively old and have a lower level of education. We can also see that households that are seldom in their residence have a lower income and are younger than the average household.

4. Econometric modeling

The comparison of means in Table 1 provides some indication that lifestyle and attitudes are important in explaining the variation in household firewood demand. However, we also see that other characteristics of the household vary across the different lifestyles. Thus, the difference in firewood demand between these groups may result from the differences in the preferences for firewood by different lifestyles or differences in other important background variables, such as the size and type of residence or other household characteristics. In order to find the partial effect of lifestyle factors on firewood demand, we therefore need to conduct a regression analysis and undertake a comparison ceteris paribus.

4.1. *The distribution of firewood demand*

The dependent variable in our model is the amount of firewood the household acquired during a year, as measured in units of 70-L sacks. Fig. 1 illustrates the distribution of the number of sacks acquired by the households in our sample. As shown, the distribution of our data is strongly skewed to the left, with many zero observations: about 41% of the sample did not acquire any firewood during the previous 12 months (see also Table 1). In such cases, the ordinary least squares estimator of a linear regression is biased and inconsistent. Even if we were to use only positive observations of the dependent variable, we would be unable to reduce this bias [26]. Therefore, we need to use a model that can include a dependent variable with many zero observations. Furthermore, the unconditional variance of our dependent variable (56.34 sacks) is much larger than the mean (36.30 sacks). This is an indication of overdispersion, which is quite common for count data with excess zeros [26]. Both the overdispersion and the excessive number of zeros in our data suggest we may have an additional problem with unobserved heterogeneity.

As information on the ownership of a woodstove is not available in our data, we do not know whether the zero observations result from a corner solution or the lack of consumption opportunities. A standard Poisson model is not an appropriate choice in this case because it only accounts for observed heterogeneity and cannot deal with excess zeros and overdispersion. To account for the excessive zero problem, we require a zero-inflated model [27] with a negative binomial regression model to correct for the overdispersion. Thus, we apply a zero-inflated negative binomial (ZINB) model with a different probability model for the zero and nonzero counts.

4.2. *Zero-inflated negative binomial model*

The zero-inflated model assumes that there are two unobserved groups: "always zero" and "not always zero" [28]. In our case, the "always zero" group is equivalent to households that lack a (working) woodstove or fireplace. The "not always zero" group are households that have opportunities to consume and can then either choose zero (corner solutions) or any positive amount of firewood consumption. Zero-inflated models estimate two equations simultaneously, one for the count model of the number of sacks acquired, and one for the probability of belonging to the "always zero" group. The probability density of firewood consumption is thus a discrete–continuous mixture of consumers with positive consumption and consumers with zero consumption on firewood. By increasing the conditional variance and the probability of the zero counts, it can

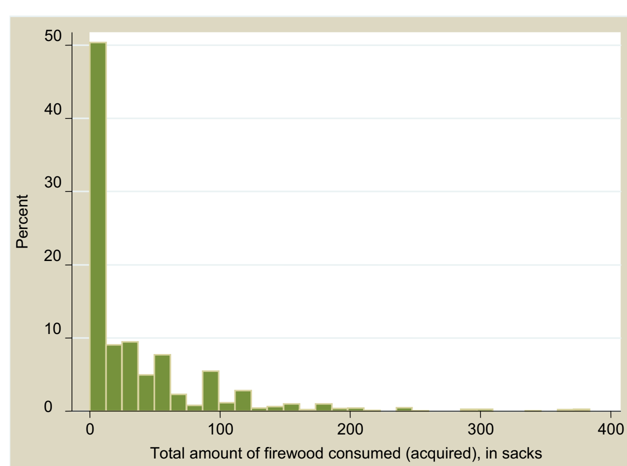

Fig. 1 – Amount of firewood consumed (acquired) by Norwegian households, in sacks[a].
[a]Histogram is drawn using percentages with Stata 12 (bin = 31, start = 0, width = 12.38).

take into account situations where the difference processes generate the zeros.

In the estimation, we refer to the "always zero" group as Group A. As shown in equations (2) and (3), a binary choice model determines household group membership, where π_i denotes the probability of belonging to Group A, and μ_i is the expected utility of firewood consumption:

$$\pi_i = \Pr(A = 1|z_i) \tag{2}$$

$$\mu_i = \exp(x_i\beta) \tag{3}$$

The z-variables are explanatory variables for the inflated model while the x-variables are explanatory variables for the count model. We specify different explanatory variables for the count equation and the inflated equation in our model. A = 1 means households do not have the opportunity to consume firewood. Equation (4) provides the overall probability of a zero count and a positive count in the data:

$$\Pr(y_i = k) = \begin{bmatrix} \pi_i * \Pr(y_i = 0|x_i, A_i = 1) + (1-\pi_i) * \Pr(y_i = 0|x_i, A_i = 0) & \text{if} \quad k = 0 \\ \pi_i * \Pr(y_i = k|x_i, A_i = 1) + (1-\pi_i) * \Pr(y_i = k|x_i, A_i = 0) & \text{if} \quad k = 1, 2, \ldots \end{bmatrix} \tag{4}$$

where y_i denotes the count number of sacks of firewood acquired and k is the observed count for all the households. Note that the overall rate of probability of zero and positive components mix according to their proportions in the population. The likelihood function is built to distinguish between consumers with different consumption opportunities [29].

4.3. *Specification of the demand for firewood*

Empirically, we specify the deterministic function for the count model in equation (5):

$$\begin{aligned}\mu_i = \exp(&\beta_0 + \beta_1\text{saving}_i + \beta_2\text{urban}_i + \beta_3\text{comfort}_i + \beta_4\text{time}_i \\ &+ \beta_5\text{environment}_i + \beta_6\text{detachedhouse}_i + \beta_7\text{farmhouse}_i \\ &+ \beta_8\text{apartment}_i + \beta_9\text{housesize}_i + \beta_{10}\text{livyrs}_i + \beta_{11}\text{city}_i \\ &+ \beta_{12}\text{cottage}_i + \beta_{13}\text{price}_i + \beta_{14}\text{income}_i + \beta_{15}\text{edu}_i + \beta_{16}\text{age}_i + \varepsilon_i)\end{aligned} \tag{5}$$

Column 1 in Table 1 lists the descriptions of the explanatory variables. In the model, we assume that each household's firewood consumption may reflect its lifestyle, social identification, and attitudes to comfort, time, and environment, and other demographic factors, such as income, education, age, etc. In equation (5), ε_i is the error term and $\exp(\varepsilon_i)$ is gamma distributed with a mean of unity and variance α [30].

5. Results and discussion

Tables 2 and 3 provide the estimation results from the ZINB continuous count and binary equations, respectively. The estimated parameters and the respective z-statistics are in columns 1 and 2. Asterisks indicate the levels of significance for the estimated parameters. In order to obtain a better understanding of the estimated coefficients in the ZINB model, we also report the percentage change in the expected count predicted by the estimation from a one unit and one standard deviation increase in the explanatory variables (see columns 3 and 4). Following Long and Freese [28], we use Stata 12 for all estimations and post-estimation calculations. We tested the model fit of the ZINB model against a zero-inflated Poisson (ZIP) model. While both models generated quite similar results, the ZIP results are more significant. However, not correcting for overdispersion normally results in consistent, yet inefficient estimation of the dependent variable. And the results are exemplified by spuriously large z-values and small *p*-values because of downwardly biased standard errors [31]. We suspect that this might be the case using our data. Thus, we only report the results of the ZINB model.

As shown in Tables 2 and 3, most of the estimated coefficients are statistically significant at the 5% level and with their expected signs. The overdispersion index, alpha (α), is statistically significant at the 1% level, which implies that applying a zero-inflated model is of benefit. In addition, the z-value of a Vuong test of the ZINB model vs. a standard negative binomial model is 15.51, suggesting that the ZINB better fits our sample than a standard negative binomial estimator [32].

Note that when the same variables are included in both the count model and the binary equation, the signs of the corresponding coefficients from the binary equation often lie in the opposite direction of those from the count equation (compare Tables 2 and 3). This is because a positive sign on a coefficient in the binary choice estimation implies a lower probability of the opportunity to use firewood, whereas a negative coefficient in the count model indicates low firewood consumption. As the binary estimation (reported in Table 3) only defines the likelihood for observations having strictly zero counts, our interpretation of the results will focus on the results from the continuous part of the estimation, as we are primarily interested in how various factors affect the amount of firewood households consume.

5.1. *Lifestyle factors*

The results generally indicate that several household lifestyle factors have a significant impact on firewood consumption. In particular, households with a more *urban lifestyle* use significantly less firewood, in that a one unit increase in the index of urban living style brings about a 15% decrease in the expected count of the number of sacks of firewood acquired. These results indicate that households that frequently participate in city life activities, such as going to the cinema, restaurants, etc., use less firewood than other households, ceteris paribus.

Table 2 – Estimation results from the continuous part of the zero-inflated negative binomial model (number of sacks acquired).

Explanatory variables	*b*	z	*p*-Value	%X	%StdX
Identifications and attitudes:					
Involved in electricity-saving behavior (0, 1)	0.116	1.520	0.128	12.3	5.2
Urban living style (1,..., 5)	−0.161**	−2.408	0.016	−14.8	−8.2
Comfort concern index (1,..., 5)	−0.058**	−2.122	0.034	−5.7	−6.3
Time spent outside house (hours per week)	−0.003	−1.279	0.201	−0.3	−3.9
Environmental concern index (1,..., 5)	−0.005	−0.103	0.918	−0.5	−0.3
Dwelling factors:					
Living in detached house (0, 1)	0.355***	3.688	0.000	42.7	18.7
Living in farmhouse (0, 1)	0.622***	4.582	0.000	86.3	18.6
Living in apartment (0, 1)	−0.333**	−1.951	0.051	−28.4	−9.2
Size of dwelling (10 m^2)	0.008	1.351	0.177	0.8	4.9
Total years in current residence (10 years)	0.086**	2.237	0.025	9.0	10.0
Living in cities (0, 1)	−0.318***	−3.231	0.001	−27.2	−12.2
Owning cottage in the mountains (0, 1)	0.228***	2.516	0.012	25.6	7.8
Demographic factors:					
Price of firewood (Euro)	−0.080***	−7.361	0.000	−7.7	−18.1
Household yearly income after tax (125 Euro)	0.0002	0.733	0.463	0.0	3.0
Education level (1,..., 8)	−0.085***	−3.449	0.001	−8.2	−11.7
Age of the main income contributor (10 years)	−0.109***	−3.030	0.002	−10.3	−13.0
Constant	4.923***	15.86	0.000		
Overdispersion factor	−0.445***	−7.93			
LR $\chi^2(16) = 216.83$	Prob > $\chi^2 = 0.0000$				
Log-likelihood	−4082.16				
N	1155				

*$p < 0.10$, **$p < 0.05$, ***$p < 0.01$.
b = raw coefficient. z = z-score for test of $b = 0$. $P > |z|$ = *p*-value for z-test. %X = percent change in expected count for one unit increase in X. % StdX = percent change in expected count for one standard deviation increase in X.

Households that score high on the *comfort* index are also likely to consume less firewood, such that when the comfort index increases by one unit, households use 5.7% less firewood. Firewood heating requires a number of daily labor inputs, including fetching the firewood, feeding the fire, and the cleaning out of ash and other residue. Even if some households experience that the fireplace brings comfort, this is not sufficient to make the overall effect positive.

The effect of being an *electricity saver* is not significant, contrary to our expectations, as using firewood to heat the residence is one of the most effective ways to save electricity. In addition, in the estimation, the index for *time used outside the house* is not significant. This is somewhat surprising, as we expected households that allocate more time on activities outside the house to consume relatively less firewood. In addition, it is also somewhat surprising that the coefficient for

Table 3 – Estimation results from the discrete part of the zero-inflated negative binomial model (probability of belonging to the "always zero" group).

Explanatory variables	b	z	P > z	%
Involved in electricity-saving behavior (0, 1)	−0.254*	−1.741	0.08	−22.3
Urban living style (1,..., 5)	0.082	0.630	0.529	8.5
Comfort concern index (1,..., 5)	0.074	1.293	0.196	7.8
Living in detached house (0, 1)	−0.382**	−2.188	0.029	−31.8
Living in farmhouse (0, 1)	−1.290***	−3.970	0.000	−72.8
Living in apartment (0, 1)	0.369	1.397	0.162	44.7
Size of dwelling (10 m^2)	−0.061***	−4.307	0.00	−5.9
Living in cities (0, 1)	0.152	0.875	0.38	16.5
Owning cottage in the mountains (0, 1)	−0.572**	−2.712	0.007	−43.6
Education level (1,..., 5)	0.138***	2.948	0.00	14.8
Age of main income contributor (10 years)	0.1521***	2.884	0.00	16.4
Constant	−0.735	−1.48		
N	1155			
Vuong test	z = 15.51 Pr > z = 0.0000			

*$p < 0.10$, **$p < 0.05$, ***$p < 0.01$.
b = raw coefficient. z = z-score for test of $b = 0$. $P > |z|$ = *p*-value for z-test. %X = percent change in expected count for one unit increase in X. % StdX = percent change in expected count for one standard deviation increase in X.

the household's *environmental attitude* index exhibits a negative and insignificant effect on firewood use. This is interesting, as Table 1 showed that these households had higher firewood consumption than the average household. This indicates that we can attribute the higher firewood consumption in households with strong environmental concerns to differences in other variables, such as the age, type, and size of the residence. Thus, even if we observe that environmentally conscious households on average use more firewood, we cannot deduce that this is because of their environmental concerns (as we might have done if only considering the results in Table 1). This illustrates the importance of a multivariate estimation in assessing the partial effect of any variable.

5.2. Household and residential characteristics

The results show a large and very significant effect of the price of firewood on the demand for firewood, such that a one standard deviation increase in the price of firewood results in an 18% decrease in the expected number of sacks of firewood acquired. This is the third largest effect in the estimations as measured by a one standard deviation increase in the explanatory variable. This indicates that cheap access to firewood is one of the most important contributors to explaining firewood consumption in Norwegian households, and that economic considerations are very important when determining how much firewood is used for heating. However, the income variable is not significant, suggesting that the use of firewood is distributed over all income groups.

We can see from Table 2 that dwelling factors and household demographics are also very important determinates of household firewood consumption. These factors describe the heterogeneity in preferences across households, and the limitations in the opportunities of the household to choose between the various energy sources. In addition, they describe differences in the needs between households with respect to providing heating services for household members.

Variables describing the type of residence, residence characteristics, and the ownership of cabins all have a very strong and significant effect on firewood consumption. Living in *detached houses* and *farmhouses* and *owning a cottage* in the mountains all have a significant positive impact on total firewood consumption. The expected purchases of firewood increase by 43% and 86% respectively for households living in detached houses or farmhouses, while owning a cottage in the mountains increases the acquired amount of firewood by 26%. Conversely, households living in apartments acquire about 28% less firewood compared with other households. We can also see that living in one of the five largest cities in Norway reduces household firewood purchases by 27%. The results also indicate that households living longer in their *current place of residence* increase the number of sacks of firewood acquired, as does households living in larger houses.

With respect to the other demographic factors, we can see that firewood demand decreases with the *age* of the main income contributor in the household. This is a somewhat different finding from that in a US study by Liao and Chang [33]. They found that the space heating energy requirement increases as the aged become older, but with increased use of natural gas and fuel oil as alternatives to electricity. However, firewood consumption involves daily labor and hard work; older households may then prefer to reduce their use of firewood for heating as they age. *Education level* also exhibits a negative relationship with firewood consumption, and it is very significant and relatively large in magnitude. We do not know the exact reason for this observation, but one may be that households with higher education often work longer hours and therefore have less time available (or need) for burning firewood at home.

5.3. Characteristics of the "always zero" households

Table 3 provides the results from the ZINB model estimation for households that fall into the "always zero" group. Note that the estimated coefficients in this table have signs opposite to their equivalent coefficients in the continuous model reported in Table 2.

As shown, living in detached houses and farmhouses significantly reduces the probability of belonging to the "always zero" group. We also find that owning a large house and/or a cottage in the mountains has a significant and negative effect on the probability of "always zero" whereas this probability increases significantly with the age and education level of the household's main income contributor.

6. Policy implications and concluding remarks

By merely considering the mean amounts of firewood consumed in different types of households (see Table 1), it would appear that households living an urban lifestyle, that are comfort seekers or energy savers, and households that spend little time in their residence, use less firewood than the average household, whereas households that are environmentally concerned use more firewood than the average household. If we compare this with the results from the ZINB estimation, we find that only urban lifestyle and comfort concerns have significant effects on firewood demand, while environmental concerns do not influence firewood consumption in a significant way.

Based on our findings, we conclude that even if the results indicate that household energy demand is significantly associated with some lifestyle and comfort indices, dwelling factors and other household characteristics are of far more importance. Households in farmhouses in the countryside do rely more on firewood for space heating. Owning a cabin in the mountains is also very important for firewood demand, as the main heating source in these cabins remains predominantly firewood. Demographic factors are also important in explaining total firewood demand. Finally, price has a very strong and significantly negative effect on firewood demand, although it does not appear that the demand is very income sensitive.

As a result, it may be difficult to identify efficient policy tools for increasing firewood demand. Most information campaigns attempt to influence attitudes and/or lifestyles. According to our findings, this will only have a limited effect on firewood demand, whereas those factors that can change demand significantly are more difficult to target using conventional policy measures. For instance, the price incentive appears strong, but it is difficult to influence consumer prices, as there are currently no energy taxes on firewood consumption in Norway. This means that governmental intervention intended to influence household firewood consumption through changes in relative energy prices must be through indirect changes in the taxes on electricity and fuel oils. This will be much less effective than a change in the own price, even if electricity and fuel oils are alternatives to firewood in consumption, as the cross price elasticities are relatively small [34]. One alternative would be to apply policies aimed at changing the supply of firewood, resulting in a reduction in the price of firewood. This may indeed increase the demand for firewood, as we identify a high level of price sensitivity in our estimation. Whether this is an optimal solution, however, remains a topic for future discussion.

The results also indicate that comfort-seeking and older people are less likely to use firewood for heating. Thus, woodstove technologies that require less labor could possibly assist in increasing the use of bioenergy in Norwegian residences. In an effort to induce such a change, the Norwegian government is subsidizing investment in pellet stoves. However, Norwegian households prefer old-style woodstoves to the more modern pellet stoves [1], and even after almost a decade of subsidies, less than one percent of Norwegian households currently own a pellet stove. This indicates that it may prove very difficult to make bio-energy more accessible and easy to use in a way that Norwegian homeowners find attractive and desirable.

One limitation of this analysis is that the underlying survey is more than a decade old, and one may expect that relative prices, household behavior patterns and heating technologies have changed much since then. In particular, heat pumps have become popular in Norwegian residences during the last decade, with approximately one-quarter of all Norwegian homes now owning a heat pump [2]. However, the use of firewood remains very popular, and 70% of households have also upgraded or are still using their woodstoves [1]. This means that the underlying preferences for firewood consumption have been relatively stable during this period, even after the introduction of alternative new technology. The use of firewood also serves purposes not given by other heating sources, such as providing coziness in front of the fireplace.

In addition, we do not expect the effects of lifestyle on firewood consumption to change that much as the new technologies introduced have little influence on how lifestyle factors affect firewood consumption. The largest effect of the new technologies, particularly air-to-air heat pumps, is presumably through the effect they have on the cost of using electricity to heat the residence. Unfortunately, we do not have information about this cost nor the cost of using fuel oil for heating in this data set. However, we do know from other studies that these indirect price effects are not very large [34].

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