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Households' heating investments: The effect of motives and attitudes on choice of equipment

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ABSTRACT

This paper reports on an online survey conducted in Norway to investigate how attitudes, motives, residence characteristics and socioeconomic factors relate to households' investments in four types of heating equipment: woodstoves, pellet stoves, electric heaters and air-to-air heat pumps. First, we find that perceptions about characteristics such as appearance, efficiency, cost, time and effort required to use the equipment, and environmental impact differ greatly between the four types of heating equipment. Second, we find that 52% of the households invested more than €375 in heating equipment in the previous 10 years, and that 34% of those invested in at least two types of heating equipment. Third, using discrete choice models, we find that motive, environmental attitude, characteristics of the residence and demographic factors affect households' heating investment likelihood and choice of heating equipment. For example, we find that people whose main motive is to reduce costs are more likely to invest in heat pumps, whereas investors in pellet stoves are more concerned about the environment.

1. Introduction

In order to achieve sustainable development, the use of renewable energy carriers and improvements in energy efficiency have become high on the political agenda in many countries, including Norway [1,2]. In particular, the use of biomass has attracted great attention because of its perceived role in reducing CO_2 emissions by partly replacing fossil fuels while also achieving sustainable social development objectives [3]. Furthermore, the Norwegian government wants to reduce reliance on electricity in residential space heating [4] and improve energy saving and efficiency [5]. Therefore, Norwegian households have been encouraged to invest in heating equipment based on renewable energy sources, such as pellet stoves, efficient woodstoves and heat pumps [6]. Achieving these goals and developing an efficient environmental and energy policy require better understanding of consumers' choice of heating equipment, in terms of what affects their decisions on whether to invest in new heating equipment and on what type of equipment to invest in.

The choice process is shaped by both economic factors, such as cost and income, and cognitive elements, such as subjective norms, attitudes and perceived controls [7,8]. In the case of heating investments, consumers make their choices subject to a series of economic and noneconomic constraints. The latter could be physical constraints (e.g., characteristics of the residence such as its age or size) and/or legal constraints (e.g., ownership status, regulations and legislation). Heating investment behavior is also shaped by consumer attitudes regarding the expected performance of the equipment and the

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energy sources being used [9,10]. Although investing in new heating technology is a way to improve heating performance and energy efficiency, such investments can also fulfill other needs, such as increasing comfort and/or improving the appearance of the home.

Most previous heating equipment choice studies emphasize the effects of income and prices on household energy consumption [11–17]. However, a few Nordic studies have included consumers' attitudes when explaining household investment in new heating equipment [9,10] [17]. Nyrud et al. [9] documented that heating performance, perceived time and effort required to operate the stove, environmental effects and perceived subjective norms influenced households' choices of woodstoves. Sopha et al. [10] found that communication between households and the perceived importance of heating equipment attributes affected households' plans for future investments in heating equipment. Mahapatra and Gustavsson [17] showed that economic aspects, functional reliability and indoor air quality were the important influencing attributes when households were choosing a heating system. However, each of these three studies has several limitations. For example, Nyrud et al. [9] studied only households in the city of Oslo that had received a subsidy for replacing an old woodstove with an improved woodstove. Sopha et al. [10] and Mahapatra and Gustavsson [17], on the other hand, based their study on stated preference data, that is, what households would do if they were to invest in the future.

This study provides insights into consumer motives in purchasing energy efficient and environmentally friendly products, using a representative Norwegian sample and revealed preference data, that is, what households have already invested in. The empirical data are from a web-based survey that asked Norwegian households about their heating investment choices during the previous 10 years. We focus our analysis on investments in four types of heating equipment: woodstoves, pellet stoves, electric heaters and air-to-air heat pumps (hereafter called heat pumps). Woodstoves and pellet stoves use bioenergy, whereas electric heaters and heat pumps use electricity. First, we investigate households' perceptions regarding the characteristics of each type of heating equipment, such as appearance, efficiency, cost, time and effort required, and environmental impact. Second, we examine what proportion of households have invested in heating equipment in the previous 10 years, and how many invested in multiple types of heating equipment. Third, we investigate what influences households' decisions to invest in new heating equipment, and which factors determine what type of equipment they choose. In the investment analysis we take into consideration intrinsic factors such as motives, attitudes, perceptions and personality, in addition to socioeconomic factors and characteristics of the residence.

2. Material

2.1. Online survey

We use data from a household online survey conducted in Norway in November 2010. The total 1860 participants were drawn from two populations: the first sample was drawn from TNS Gallup's web panel, and the second from the database of Enova, the Norwegian government's agency for handling subsidies for alternative heating systems. Henceforth, we refer to the former subsample as the *Gallup sample*, the latter subsample as the *Enova sample* and the total sample as the *Combined sample*.

The Gallup sample is a national randomly selected sample, representing a cross-section of the Norwegian population. However, for the purposes of our analysis, the Gallup sample contains too few observations of investment in less frequently used equipment, such as pellet stoves. This makes it impossible to identify why people choose these types of equipment. We therefore needed to supplement the Gallup sample with the Enova sample, which includes information about households that have applied for a subsidy from Enova to invest in a pellet stove, large heat pump or other energy saving equipment. The Enova sample is randomly drawn from the database of Enova applicants.

The same questionnaire was administered to both the Gallup and the Enova samples. The questionnaire contained four sections. In Section 1, we asked about the respondents' current residence, including its type, age and size, and the resident's ownership status. We also asked about the preferred living room temperature. In Section 2, respondents were asked about the existing heating equipment and investment in heating equipment during the previous 10 years. If households did invest, we asked for more details about their investment motives, subsidies received and similar information. Section 3 of the questionnaire elicited responses on perceptions of types of heating equipment, attitudes toward the environment and personality traits. For example, respondents were asked to compare woodstoves, pellet stoves, electric heaters and air-to-air heat pumps with respect to equipment attributes such as cost, environmental friendliness, air quality, and time and effort required. For each statement, they indicated their perceptions on a seven-point scale where 1 = strongly disagree and 7 = strongly agree. We used the same seven-point scale for all attitude and perception questions. Finally, in Section 4 we asked about demographic factors, such as income, education, age and household size.

The response rates were 46% for the Gallup sample and 43% for the Enova sample.[1] The average age of respondents in the Combined sample is 47 years and the average household annual income before tax is €74,000–100,000 (1 Euro = 8 NOK; see Table 1). More men than women answered the questionnaire in both samples, and the share of men was significantly higher in the Enova sample than in the Gallup sample. The latter most likely reflects the fact that families applied to Enova for a heating investment subsidy in the name of the husband and that we therefore obtained the name of the man from the Enova database. In addition to the gender difference, there are also several minor, although statistically significant, differences between the two samples. Respondents in the Enova sample are younger and more

[1] Unfortunately, we do not have information about the respondents who chose not to participate, and therefore cannot conduct any nonresponse bias analysis.

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Table 1 – Description of the survey sample.

Variables	Measurement	Combined sample		Gallup sample		Enova sample	
		Mean	Std	Mean	Std	Mean	Std
Family income	Eight-point scale	4.23	(1.58)	3.93	(1.56)	4.57	(1.54)
Household size	Five-point scale	2.73	(1.22)	2.32	(1.07)	3.21	(1.21)
Education	Five-point scale	3.44	(1.15)	3.37	(1.16)	3.52	(1.13)
Age of respondent	In years	47.87	(12.53)	48.96	(12.99)	46.59	(11.83)
Female	Dummy	0.33	(0.47)	0.46	(0.50)	0.17	(0.38)
Size of residence	Six-point scale	3.56	(1.14)	3.24	(1.13)	3.95	(1.02)
Age of residence	In years	38.99	(23.71)	40.51	(22.61)	37.21	(24.83)
Years in residence	In years	14.18	(12.74)	15.61	(13.33)	12.49	(11.79)
Sample size		1860		1004		856	
Response rate	Percent	45		46		43	

educated, have a higher income and bigger household, live in a newer house and moved to the current residence more recently than respondents in the Gallup sample.

To measure the effect of differences in climate on a household's choice of heating equipment, we use local heating degree days (HDD) from the Norwegian Meteorological Institute, defined as the accumulated difference in degrees Celsius between the daily mean temperature (when it is $< 17\ ^{\circ}C$) and a threshold temperature of 17 °C over one year. HDD has been found to be a good indicator of heating requirements. The greater the HDD the greater the energy demand to heat the house [18].

In our samples, 78% of the households have electric *space* heating and 64% have electric *floor* heating. Woodstoves are the second most common form of heating equipment: about 69% of households have a woodstove and/or a fireplace. The proportion of households owning an air-to-air heat pump is 26%. Only about 5% of the households own an oil/paraffin stove and/or a central heating system fueled by oil. As the Enova sample is drawn from the database of prior applicants to Enova, the share of households owning pellet stoves in the Enova sample is 31%, which is much higher than the share in the Gallup sample (0.5%).

2.2. *Perceptions of the types of heating equipment*

Perceptions play a very important role in consumer decision making process [8]. It is usually the perceived attributes, rather than the actual attributes, that determine choices.

Table 2 provides information about households' perceptions of the attributes of each type of heating equipment. In general, woodstoves scored high on appearance, effectiveness in warming up the house and heating costs, but respondents perceive that woodstoves require more time and effort to operate, as do pellet stoves. Pellet stoves are considered to be environmentally friendly, although not as much as heat pumps. Households also think that it is more difficult to get hold of pellets than firewood. Electric heaters are perceived as the best choice in terms of low investment costs and indoor air quality. Households perceive heat pumps to be the best investment in terms of operating cost, indoor air quality, environmental friendliness and effectiveness in warming up the house; however, heat pumps are perceived to have high investment costs and they scored low on appearance.

Each type of heating equipment has its own advantages and disadvantages, and no one type scores highest for all attributes. Households are likely to choose the equipment they think will best meet their specific needs.

2.3. *Investment choices*

In the Gallup sample, 52% of survey respondents reported that they had invested in at least one piece of heating equipment in the previous 10 years.

Table 3 shows the frequency of heating investment by Norwegian households. Results from the Gallup sample and the Enova sample are reported separately. Column 1 reports the frequency of investment in each of the four types of heating equipment. Columns 2 to 5 give the percentage of households that invested in a second piece of equipment, having also invested in the equipment reported in column 1. The proportions of households investing in woodstoves, pellet

Table 2 – Mean scores of perceptions of attributes of each type of heating equipment.

Perception of attributes	Electric oven	Firewood stove	Pellet stove	Air-to-air heat pump
Investment cost is low	5.67 (1.63)	3.75 (1.65)	2.59 (1.49)	3.08 (1.70)
Annual heating cost is low	2.79 (1.58)	5.09 (1.67)	4.03 (1.68)	5.22 (1.55)
Effectively warms the house	4.32 (1.75)	5.39 (1.49)	5.17 (1.48)	5.85 (1.27)
Difficult to obtain heating fuel		1.83 (1.40)	3.67 (1.95)	
Environmentally friendly	4.23 (1.98)	4.29 (1.71)	5.12 (1.47)	6.09 (1.13)
Takes much time and effort	1.31 (0.84)	4.17 (1.74)	3.82 (1.53)	1.62 (1.16)
Worsens air quality	4.32 (1.84)	3.55 (1.71)	3.33 (1.48)	2.65 (1.69)
Its appearance fits the house	4.81 (1.87)	5.48 (1.69)	4.35 (1.94)	3.85 (2.01)

Note: Means with standard errors in parentheses. All items are measured on a 7-point scale, where 1 = strongly disagree and 7 = strongly agree. Gallup sample: $N = 1004$.

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stoves, electric heaters and heat pumps were 20%, 0.5%, 15% and 17%, respectively. Many households invested in more than one piece of heating equipment; some had bought even three of the four types. For example, among households that invested in a woodstove in the Enova sample, 49% also invested in an electric heater, 29% invested in a heat pump and 24% invested in a pellet stove.

2.4. Motives behind heating investments

Table 4 lists the key reasons that respondents gave for their investment decision. Only households that had made at least one heating investment during the previous 10 years answered this question. They chose the relevant ones from a list of motives, and multiple motives were allowed.

The most common motive chosen was to reduce heating costs. In the Gallup sample, 61% of the respondents gave this as the purpose of their heating investment, while 38% of households said they invested in order to improve indoor air quality and 33% to replace worn-out equipment. This last response is closely related to a household's decision to renovate the house, which was a motive given by 32% of households. Saving time or effort in heating the house was selected as a motive for 22% of the households. Improving local air quality and reducing greenhouse gas emissions was a motive for 18% and 12%, respectively. This indicates that the environment is not an important consideration for most people when investing in heating equipment.

3. Econometric approach

To determine the importance of the perceptions, motives and characteristics of the households and residences to the households' investments in heating equipment, we estimate two discrete choice models. The first model is a binomial logit model exploring the decision to invest or not, and the second model is a mixed logit model exploring the choice of equipment to invest in. Both are random utility models [19].

In the first model, the heating investment decision is represented by a dummy variable, indicating whether the household invested in heating equipment during the previous 10 years. This decision is assumed to be influenced by a number of factors, including the investment motives, attitude toward environmental factors, personality traits (e.g., degree of procrastination, willingness to throw away old equipment, preferred room temperature) and characteristics of the household and residence (income, education, age of household members, residence type, ownership status, and size and age of the residence). The household is assumed to invest in new heating equipment if the investment increases its utility. In our estimation, the utility of the investment (which equals the difference in utility before and after the investment) is approximated by equation (1):

$$V_i = \beta_0 + \gamma' x_i + \varepsilon_i \quad (1)$$

where V_i is the utility that household i derives by investing relative to not investing; β_0 is the constant; x_i is a vector of residence factors, demographic factors, attitudes and perceptions and sample indicators associated with respondent i; γ is the corresponding vector of parameters and ε_i is the disturbance term, which is assumed to satisfy the standard assumptions of the logit model. For a detailed list of the explanatory variables, see Table 5.

In the second model, we estimate the probability that a household will choose a particular type of equipment once it has decided to invest. We restrict our choice set to four heating alternatives: woodstove, pellet stove, electric heater and air-to-air heat pump. As one household may invest in more than one type of heating equipment, we specify a panel version of the mixed logit model with random-effect alternative-specific constants (ASC). If a household invested in more than one type of heating equipment, we give each of the n choices a weight of $1/n$ in the estimation. Furthermore, because the Enova sample is not representative of the Norwegian population, we also generate sampling weights in the Enova sample to balance the proportional differences between the Gallup sample and the Enova sample [20,21]. The weighted Enova sample used in the estimations has the same

Table 3 – Investments and cross-investments in heating equipment (in percentages).

Investment			Cross-investment frequency[a]			
Equipment	Sample	Frequency	Woodstove	Pellet stove	Electric heater	Heat pump
Woodstove	Gallup	0.20	1.00	0.00	0.32	0.30
	Enova	0.20	1.00	0.24	0.49	0.29
Pellet stove	Gallup	0.005	0.00	1.00	0.20	0.60
	Enova	0.23	0.21	1.00	0.21	0.19
Electric heater	Gallup	0.15	0.42	0.006	1.00	0.21
	Enova	0.23	0.43	0.22	1.00	0.19
Heat pump	Gallup	0.17	0.35	0.012	0.19	1.00
	Enova	0.15	0.41	0.30	0.30	1.00
Investing households in total	Gallup	0.52				
	Enova	0.89				

a The first two rows of the cross-investment frequency report the conditional frequency of those in the Gallup and Enova samples that say they invested in a woodstove and also invested in one or more other types of equipment. The following rows indicate the same information for other equipment types, respectively.

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Table 4 – Motives for heating investment (in percentages).

Heating investment motives	Combined sample	Gallup sample	Enova sample
To reduce heating costs	72.54	61.10	80.45
To improve indoor air quality	41.58	38.14	43.96
To replace broken appliance	30.02	32.64	28.22
To modernize equipment	33.05	32.45	33.46
To save time and effort in heating	29.17	22.20	33.99
To improve local air quality	22.96	17.65	26.64
To reduce greenhouse gas emissions	22.11	12.14	29.00
Previous one did not look good	7.76	9.49	6.56
To increase house sale value	7.60	3.98	10.10
N	1289	527	762

Note: All motives were asked as yes/no questions, and multiple motives were allowed.

investment distribution as the Gallup sample. The same holds for the Combined sample.

In the mixed logit estimation, we assume that the household chose to invest in the equipment that afforded the highest utility level. We assume that the utility derived from each type of heating equipment depended on personal characteristics such as the owner's investment motives and socioeconomic factors, as well as on external factors, such as residence characteristics and climate. For identification, we normalize the utility of electric heaters to be zero, and model the utility from choosing one of the three other types of equipment relative to the utility of the electric heater. We approximate this utility difference by equation (2):

$$V_{ij} = \beta_{0ij} + \gamma_j' x_i + \varepsilon_{ij} \quad (2)$$

where V_{ij} is the utility household i receives by investing in heating equipment j, where j represents woodstove, pellet stove or heat pump, relative to investing in electric heaters; β_{0ij} is the random-effect ASC for alternative j, which is heteroskedastic and independently normally distributed over alternatives; x_i is a vector of residence factors, demographic factors and investment motives for respondent i; γ_j is the corresponding vector of nonrandom parameters associated with alternative j; and ε_{ij} is the disturbance term, which is assumed to fulfill standard logit assumptions. For a detailed list of explanatory variables, see Table 6.

Stata 12 software [22] was used for the econometric analyses. Equation (2) was estimated using the Stata mixlogit command described in Hole [23], Cameron and Trivedi [24] and Long and Freese [25].

4. Results and discussion

4.1. *The investment choice*

Table 5 shows the results of the binomial logit model exploring the decision to invest or not, using the Combined sample, the Gallup sample and the Enova sample.

Table 5 – Results from a logit estimation on the heating investment choice.

Explanatory variables	Measurement	Combined sample	Gallup sample	Enova sample
Attitudes and perceptions				
Preferred living room temperature	Four-point scale	0.283**(−0.107)	0.438***(−0.128)	−0.068(−0.208)
Attitude to environmental responsibility	Seven-point scale	−0.109**(−0.053)	−0.132**(−0.064)	−0.080(−0.097)
Buyer of environmentally friendly products	Seven-point scale	0.142**(−0.046)	0.129**(−0.056)	0.189**(−0.083)
Procrastination	Seven-point scale	−0.083**(−0.037)	−0.087**(−0.044)	−0.091(−0.074)
Unwilling to dispose of old equipment	Seven-point scale	−0.067*(−0.037)	−0.079*(−0.044)	−0.031(−0.069)
Demographic factors				
Household income	Eight-point scale	0.087**(−0.036)	0.117**(−0.041)	−0.041(−0.079)
Education level	Five-point scale	−0.098*(−0.058)	−0.123*(−0.068)	−0.017(−0.116)
Age of respondent	In decades	0.054(−0.057)	0.0397(−0.068)	0.045(−0.115)
Household size	Five-point scale	0.112*(−0.067)	0.134(−0.084)	0.063(−0.116)
Residence factors				
Apartment	Dummy	−1.470***(−0.217)	−1.413***(−0.246)	−1.521**(−0.495)
Age of residence	In decades	0.177***(−0.029)	0.149***(−0.035)	0.238***(−0.055)
Own the residence	Dummy	1.222***(−0.241)	1.261***(−0.262)	1.054(−0.857)
Size of residence	Six-point scale	0.230***(−0.069)	0.281***(−0.082)	0.178(−0.137)
Sample factors				
Gallup sample	Dummy	−0.922***−0.175		
Received Enova subsidy	Dummy	1.344***(−0.253)		1.391***(−0.26)
Constant		−2.023**(−0.643)	−3.211***(−0.731)	−0.975(−1.51)
N		1742	943	799
Log likelihood		−787.099	−534.848	−243.753

Note: Dependent variable equals 1 if household has installed new heating equipment costing more than €375 in the past 10 years, zero otherwise. Standard errors in parentheses. *$p < 0.10$, **$p < 0.05$, ***$p < 0.001$.

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Overall, the results for the Combined sample and the Gallup sample are similar to each other, and the results for the Enova sample are slightly different. In general, residence characteristics, income, education, environmental attitudes, time preference and unwillingness to throw away old equipment significantly influenced households' heating investments. First, *attitudes and perceptions* provide a mixed picture. People who are more environmentally concerned are less likely to invest, but being a buyer of green products increases the investment likelihood. This indicates that environmentally aware consumers who express their concern through the products they choose are also more likely to invest in new and energy efficient equipment. For time preferences, we find that respondents who procrastinate have a reduced likelihood of investing, as do people who do not like to throw away old equipment. Finally, households that prefer higher room temperatures are more likely to invest in new heating equipment.

Second, *demographic factors* also play an important role in the investment likelihood. In the Combined sample and the Gallup sample, we find that higher income is associated with an increased likelihood of investment, while a higher education level is associated with a lower investment probability. There is no significant relationship between respondent's age and investment likelihood. Household size is only significant in the Combined sample, and it implies that larger households are more likely to invest.

Third, *residence characteristics* seem to be the most significant factors associated with investment likelihood. The results for all three samples imply that households living in an older house are more likely to invest. Living in an apartment significantly reduces the probability of investment, possibly because of the availability of common heating systems. Results for the Combined sample and the Gallup sample provide further evidence that the size of the house and being the owner of the house have significant positive effects on the investment likelihood. Bigger houses need more heating and ownership of the house increases the incentive to invest.

Finally, households *applying for subsidies* from the government had a higher investment probability than those that did not. This correlation is likely a result of applicants for subsidies having already decided to invest before applying for the subsidy.

4.2. The choice of heating equipment

Equation (2) focuses on the drivers behind the choice of each type of heating equipment. In this estimation, we use the Combined sample in order to explore the purchases of the less common equipment, such as pellet stoves. The model is estimated relative to investments in electric heaters, meaning that the coefficients measure the difference in utility of choosing another type of equipment relative to electric heaters, given that the household has decided to invest.

Table 6 – Results from a mixed logit estimation of investment in woodstoves, pellet stoves and heat pumps relative to electric heaters.

Explanatory variables	Measurement	Estimated coefficients			Differences and Wald test		
		Firewood	Pellet	Heat pump	F–P	F–H	P–H
Investment motives:	Dummies						
To reduce heating costs		−0.132	−0.118	1.015***	−0.014	−1.147***	−1.133***
To increase house sale value		0.458	−0.226	−0.637	0.684	1.095*	0.411
Previous one did not look good		0.090	−1.382**	−1.533***	1.472**	1.624***	0.151
To replace broken appliance		−0.558**	−0.853***	−1.412***	0.295	0.854***	0.558*
To modernize equipment		−0.183	−1.140***	−0.810***	0.958**	0.628**	−0.330
To save time and effort in heating		−0.075	1.673***	0.890***	−1.748***	−0.965***	0.783**
To improve indoor air quality		−0.334*	−0.212	0.602**	−0.122	−0.936***	−0.814***
To improve local air quality		0.185	0.288	0.179	−0.103	0.006	0.109
To reduce climate change gas emissions		0.498*	0.906**	−0.170	−0.408	0.668*	1.076**
Demographic factors							
Household income	Eight-point scale	−0.068	−0.122	0.041	0.054	−0.110	−0.164*
Household size	Five-point scale	−0.051	0.265*	−0.090	−0.316**	0.039	0.355**
Age of respondent	In decades	0.162*	0.125	0.197*	0.037	−0.035	−0.072
Education level	Five-point scale	−0.086	−0.078	−0.139	−0.009	0.053	0.062
Residence factors							
Detached house	Dummy	0.630**	0.372	0.820***	0.258	−0.191	−0.448
Size of residence	Six-point scale	0.102	0.247*	0.234*	−0.145	−0.132	0.013
Age of residence	In decades	−0.023	0.035	−0.035	−0.058	0.012	0.071
Mean heating degree days	In 100 HDD	0.015	0.060**	0.004	−0.045**	0.011	0.056**
ASC		−0.722	−9.081***	−2.214**	8.359***	1.492	−6.867***
Std of ASC		0.544*	1.276	0.141	0.731	0.686	1.417

Number of choice observations = 1220
Number of participants = 826
Log likelihood = −618.39
Wald $chi^2(54) = 396.37$
Prob > $chi^2 = 0.0000$
Note: Estimated with the mixlogit command in Stata 12. *$p < 0.10$, **$p < 0.05$, ***$p < 0.001$.

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Included in the estimation are 826 households that made a total of 1220 investments.

Column 1 of Table 6 lists the explanatory variables and column 2 details how they are measured. Columns 3–5 list the coefficients estimated by the mixed logit model in equation (2). Columns 6–8 show the difference in coefficients between woodstoves, pellet stoves and heat pumps. The significance levels are calculated using Wald tests of parameter equality.

The investment likelihoods for each type of equipment are significantly associated with the various explanatory variables. Starting at the top, we see that *reducing heating costs* is more important for households investing in heat pumps than for those investing in electric heaters, pellet stoves or woodstoves. This could be because of the perception that heat pumps are more energy efficient and cost saving, which is consistent with the equipment evaluation results in Table 2. The motive *to increase house sale value* is more important among households that invest in a woodstove than those that invest in heat pumps.

The next three motives focus on the replacement of old equipment. *The previous equipment did not look good* was a more important motive for households investing in electric heaters and woodstoves than for households investing in heat pumps and pellet stoves. This can be explained by the fact that electric heaters and woodstoves have been common in Norwegian houses for many years and that new and more aesthetically appealing ones have entered the market. Heat pumps and pellet stoves, on the other hand, are relatively new technologies and people have not started to replace them. Furthermore, heat pumps and pellet stoves tend not to be aesthetically appealing, as reflected in their relatively lower score for appearance in the perceived attributes reported in Table 2.

The motive *to replace a broken appliance* is most important for households investing in electric heaters and least important for those investing in heat pumps. Most households already have several electric heaters installed their home, and are more likely to buy a new one to replace old, broken equipment. It is more likely that the other three types of equipment, especially the heat pumps, are bought to supplement already existing equipment, and not as a replacement. Similar arguments can be used when investment behavior is motivated by *house renovation*.

The motive of wanting *to save time or effort in heating* was most important to households that invested in pellet stoves or heat pumps. This indicates that they wanted to replace old equipment that demanded more effort such as woodstoves in the case of pellet stove buyers and firewood or fuel oil stoves for heat pump buyers. This motive is most important for pellet stove buyers. Nyrud et al. [9] also identified maintenance work as an important determinant in the heating equipment investment decision.

As in Mahapatra and Gustavsson [17], we find that the motive of *improving indoor air quality* is important when choosing a heating system, and more important for households investing in heat pumps and electric heaters than for those investing in woodstoves and pellet stoves. Considering the dust generated during biomass-based heating processes and consumers seek for more comfort, these results seem reasonable. Our results suggest that the households that care most about indoor air quality are more likely to choose a heat pump. This finding is opposite to the findings of Sopha et al. [10], but the main difference between our study and their study is the time frame for the data collection: we collected households' actual investment data whereas they collected the stated preference data.

Interestingly, local air quality seems to be equally important for buyers of all types of equipment. Heating based on wood and pellets has a negative effect on the local air quality; however, upgrading an old woodstove to a modern wood or pellet stove has a positive effect on local air quality. As a consequence, the local government in Oslo has been subsidizing modernization of biomass-based equipment [9].

Motives concerning climate change seem to matter most for people investing in pellet stoves and woodstoves. In the case of woodstoves, this may be because people are replacing old stoves with new stoves that are more energy efficient. In the case of pellet stoves, this is consistent with households' high expectation of pellet stoves on good environmental performance (Table 2). Note that although heat pumps received the highest score on environmental performance, heat pump buyers were not motivated by environmental concerns.

Household income is positively associated with investment in heat pumps relative to pellet stoves; otherwise, household income is not significant. This minor impact of income is similar to the findings of Braun [16]. Household size is positively associated with investment in pellet stoves relative to the other three equipment types. Age is positively associated with woodstove and heat pump investments, possibly because older people are accustomed to using firewood and heat pumps are considered to be a convenient heating solution with little effort involved. These results are similar to those in Sopha et al. [10]. However, education level does not seem to be important in the choice of heating equipment in our study, in contrast to Sopha et al. [10], who found that education had an effect on the probability of choosing pellets.

Living in a detached house significantly increases the probability of investing in a woodstove or heat pump. House size is significantly and positively associated with the likelihood of investing in a pellet stove or heat pump. The age of the house is not a significant factor in the analysis. Findings from a recent German study [16] also concluded that residence features are significant in determining the heating choice.

As in Sopha et al. [10], living in a cold climate significantly increases the probability of investing in a pellet stove, compared with the other equipment types. These households typically have significant heating needs, and there are many days when it would be too cold for a heat pump to function efficiently. They are also more likely to invest in multiple types of heating equipment to reduce the risk of vulnerability to both blackouts and changes in electricity prices.

5. Conclusion

In this paper, we investigated the factors influencing households' heating investment decisions and choices of heating equipment. The aim was to improve our understanding of

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what determines household energy investment behavior. We carried out two estimations based on revealed preference data from a national household web survey. Our results have important policy implications.

Overall, the results suggest that several factors affect heating investment decisions and choices. First, the *decision* to invest is affected by both economic factors, such as cost and income, and noneconomic factors, such as residence characteristics, demographics, attitudes toward the environment, time preferences and willingness to dispose of old equipment.

Second, households' choices of equipment are influenced significantly by investment motives, residence characteristics, climate and some demographic factors. Our results suggest that Norwegians perceive different types of heating equipment very differently. We found that the cost saving motive had a significant effect on the investment likelihood for heat pumps. Woodstoves are a popular conventional heating choice and also decorate the house. Pellet stove buyers are more environmentally concerned and their investment may be influenced by the perceived environmental contribution of pellet stoves.

The majority of the households that had invested in new equipment were motivated by reducing heating costs. It is also worth noting that the two most popular types of equipment in the previous 10 years, woodstoves and heat pumps, were also the ones that the participants perceived to have the lowest annual heating costs, although not the lowest investment costs. This indicates that households are influenced not only by heating costs, but also by the investment cost, meaning that they consider the total cost of using the equipment over many years.

A comparison of the two forms of biomass-based heating equipment reveals that woodstoves are the most popular of the four types of equipment while pellet stoves are the least popular. The reasons for this difference may lie in the perceptions of the two technologies. Respondents believe it is easy to obtain firewood, while it is more difficult to obtain pellets. Woodstoves are also the favorite when it comes to cost; they are perceived to have a lower investment cost and lower annual heating costs than pellet stoves. In addition, woodstoves are more esthetically appealing than pellet stoves. Pellet stoves score better than woodstoves only in terms of the environment and the time and effort required for their operation. However, for these issues, heat pumps are considered far better than pellet stoves. Hence, if stakeholders in the pellet industry want to reach more than a small group motivated by environmental issues, they will have to improve their product in multiple ways. First, households must be able to obtain pellets easily. Second, the investment and annual heating costs must be competitive with other heating sources. Finally, improved esthetic appeal will probably increase the use of pellet stoves.

Environmental awareness appears to be a double-edged sword for biofuel-based equipment. On the one hand, being environmentally aware seems to reduce a consumer's probability of investing in new equipment. On the other hand, environmental awareness does seem to increase the probability of purchasing biofuel-based heating equipment. It is thus not obvious whether increasing environmental awareness will boost market demand for biofuel-based heating equipment. Our results indicate that information campaigns should focus more on savings in terms of money and time of using the new and more energy efficient equipment, rather than focusing on the environmental benefits.

Although this study helps us better understand Norwegian households' heating investment decisions and choices of heating equipment, we do not have information about the stock of heating equipment prior to investment, and whether the investment replaced one or more of the previous equipment types. Furthermore, we do not have information about the investment size; all we know is that each household had invested more than €375 during the previous 10 years. Finally, and perhaps most importantly, we do not have information about energy consumption. Thus, we are not able to conclude how these investments affect emissions from household stationary energy consumption. These are important topics for future research.

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