Factors Influencing Energy Efficiency Investments: a Case Study on Dutch Homeowners

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Abstract

The Dutch government's goal to become a climate neutral country necessitates the encouragement of homeowners to invest in energy efficiency measures (EEMs). To achieve this goal, policymakers need to comprehend the underlying drivers that prompt homeowners to invest in EEMs. This study aims to aid policymakers in comprehending the investment behaviour of Dutch homeowners by investigating the reasons behind their investment decision and identifying the factors that determine the amount of capital homeowners allocate to EEMs. The model of this study includes various motivational-, contextual- and personal factors that impact investment behaviour, as indicated by prior empirical studies. The findings reveal that motivational factors and the contextual factors age and building type are the most significant predictors in the investment decision as they influence the likelihood of homeowners to invest. Personal factors have the greatest impact on the investment itself, as gross household income and the availability of subsidies affect the magnitude of the investment. These findings have substantial implications for policymakers in the Netherlands, who can leverage them to design effective policies to encourage homeowners to invest in EEMs, thereby achieving their climate policy targets.

Keywords: Energy efficiency measures (EEMs), homeowners, investment behaviour

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1. Introduction

1.1 Motivation

The current state of the earth's climate is marked by a crisis that demands the accountability of all nations in minimizing environmental damage, especially concerning greenhouse gas emissions. In response, European countries have joined forces and reached a consensus on targets aimed at reducing emission levels, as established in the Paris Agreement, a legally binding international treaty on climate change. The goal is to limiting global warming to well below the 2 degrees Celsius (UNFCCC, 2016). The attainment of the Paris Agreement requires that EU member states reduce their emission levels by a minimum of thirty percent by 2030 (Rijksoverheid, n.d.). This entails the implementation of measures that affect all sectors, including the real estate industry. Collectively, buildings in the EU responsible for 40% of total energy consumption and 36% of greenhouse gas emissions, mainly due to their construction, usage, renovation and demolition. Furthermore, around 75% of the EU's building stock is energy-inefficient (European Commission, n.d.). Thus, reducing energy consumption in the real estate sector can significantly contribute to reducing air pollution, making it an important climate policy objective for many governments, including the Netherlands.

The Dutch government seeks to take a prominent role in reducing carbon emissions, driven by its position as one of the world's wealthiest countries (Legatum Prosperity Index, 2021). As a result, the country's climate policy exceeds the objectives outlined in the Paris Agreement. The Dutch government aims to reduce the national carbon emissions by 55% by 2030 and 80% by 2040, in its effort of becoming a climate-neutral country. This policy results in a focus on investing in energy efficiency measures (EEMs) to make the country's building stock more sustainable (Rijksoverheid b, 2021). For example, the Dutch office market is mandated to meet a minimum energy label C to by the end of 2022 to remain operational (RVO, n.d.). Homeowners are also encouraged to invest in energy efficiency measures to reduce energy consumption and greenhouse gas emissions. Examples of EEMs include installing solar panels, replacing old heating systems with modern ones, insulating exterior walls or replacing old windows. Households are already investing in EEMs, not only to have a positive impact on the environment but mainly to lower energy bills and increase comfort (Aravena et al., 2016). According to a study conducted by Taruttis and Weber (2022), homebuyers highly value energy efficiency. By analysing the relationship between energy efficiency and housing prices in the German owner-occupied sector, their results demonstrate that a yearly improvement of 100 kWh/m² in energy efficiency leads to an average price increase of 6.9%.

However, despite the value that sustainability holds for real estate users, the current level of energy efficiency investments do not result in a decrease in emission levels. In fact, the level of carbon emissions in the building environment was found to be 10% higher in 2021 than in 2020 (CBS, n.d.).If the Dutch government aims to achieve its ambitious targets, it is critical to encourage homeowners to invest in EEMs to rapidly reduce greenhouse gas emissions.

1.2 Literature overview

Through a comprehensive examination of empirical research employing the keywords “energy efficiency”, “Investment behaviour” and “homeowners”, Google Scholar reveals numerous relevant studies. These studies have drawn upon additional references to investigate the investment behaviour of homeowners in relation to energy efficiency measures, which also offer valuable insights to this literature review. The academic literature shows that researchers have been interested in understanding the impacts of energy efficiency for decades. One notable finding is from 1983, where Gates observed that conserving energy is one of the most profitable investments for homeowners. Nevertheless, in the context of the Netherlands, the observed energy paradox between Gates’ rates on return and the actual level of investments suggests that homeowners integrate factors in their calculations that experts have overlooked (Zundel and Stieß, 2011). These factors may include: risk and uncertainty (homeowners tend to avoid risky investments with uncertain results), sunk costs (taking earlier investments into account) and information problems (homeowners do not fully know their options) (Jaffe and Stavins, 1994; Jochem an Gruber, 1990). These explanations assume that homeowners view EEMs primarily as investments. However, it is uncertain whether such an economic perspective truly exists in the minds of homeowners. Stern (1992) contests its existence and proposes that a homeowners’ decision is aligned with their attitudes towards their homes and energy-saving measures. Thus, to explain the perceived energy efficiency gap in the Netherlands, it is crucial to study Dutch homeowners’ values and social context that shape their investment behaviour.

The applicability of findings from studies conducted in other countries to the Dutch population is limited due to the differences in homeowners’ motivation to invest in EEMs among countries. For instance, Zundel and Stieβ (2011) identified the key factors influencing energy efficiency renovation decisions among German homeowners. Their findings are consistent with those of Stern (1992), indicating that the investment behaviour of homeowners is influenced by a variety of needs, such as comfort, convenience, status and belonging. Of these, economic factors are considered the primary motivator. However, unlike Gates’ (1983) view, the economic motivation in this context does not imply that homeowners perceive EEMs as an investment calculus with a considerable positive net present value. Rather, German homeowners view energy efficiency as a protection against economic risks, like volatile prices of future supply problems. Aravena et al.’s (2016) findings align more closely with Gates’ (1983) study, as economic factors, specifically cost savings, are the primary motivator for Irish households to participate in energy-saving programs and adopt EEMs. In contrast, environmental motivations were found to have little impact. The work of Jakob (2007) yielded slightly different results, indicating that for Swiss homeowners building envelope renovation is mainly triggered by general renovation activities, such as building extensions or alterations or end-of-life of the element, but also by environmental concerns. Notably, the latter motivation results in the most significant energy-efficient renovations.

In 2011, the Organisation for Economic Cooperation and Development (OECD) conducted a cross-country analysis of household adoption of EEMs and related behavioural practices. The study contains survey-data from over 10.000 households across ten different countries, offering valuable insights into the factors contributing to variations in investment behaviour among these countries. Apart from differences in government support for EEMs, the results show significant variations among respondents in terms of their energy-saving behaviour, environmental concerns, motivations to reduce energy and their investments in EEMs. Consequently, comparing findings from studies conducted in different countries can be difficult. Moreover, cross-study comparisons conducted at different points in time may not be valid due to technological changes and differences in education level (Mills and Schleich, 2012). Besides Ebrahimigharehbaghi et al. (2022), who examined the behavioural factors that influence investments in different forms of EEMs, no significant research has been conducted on the investment behaviour of Dutch homeowners. Thus, research on the investment behaviour of Dutch homeowners is limited and due to differences in energy use behaviour, motivations to invest and institutional factors; results of other case studies cannot be generalized and applied to the Netherlands, underscoring the significance of conducting this study in its specific national context.

1.3 Research problem statement and readers guide

It is imperative for policymakers in the Netherlands to comprehend the underlying drivers that prompt homeowners to invest in EEMs and the effect of these factors on the magnitude of their investments in order to achieve their climate policy targets. Regrettably, the current literature on energy efficiency investments with a focus on the Netherlands is insufficient, which underscores the potential contribution this research can make to both the Dutch and European climate discourse. To bridge this research gap, this investigation studies the investment behaviour of Dutch homeowners regarding energy efficiency measures by the following research question: “What are the factors that drive Dutch homeowners to invest in energy efficiency measures”. This study aims to examine the factors that influence the investment decision in two distinct phases. The initial phase involves determining the factors that determine the likelihood of a homeowner to invest, while the subsequent phase focuses on identifying the factors that impact the magnitude of the investment. Prior to conducting the research, the study analyses empirical research to identify the factors that determine investment behaviour. Subsequently, chapter 3 provides an outline of the data and the methodology employed to address the research question. Thereafter, chapter 4 shows the data outcomes of the regression model. Finally, the conclusion summarizes the most significant findings, discusses the study’s limitations and outlines the policy implications.

2. Literature Review

To investigate the investment behaviour of Dutch homeowners regarding energy efficiency investments, it is imperative to gain understanding of the various factors that shape their decision-making process. This chapter analyses prior studies in order to define the key determinants of energy efficiency investment behaviour. These factors will be used in chapter 3 to develop a comprehensive conceptual framework to study the research question.

2.1 Behaviour influencing factors

Investing in EEMs is not a straightforward decision for homeowners. Therefore, policy makers should help and encourage them throughout their decision-making process. As stated in the review of the Global Energy Assesment (Ürge-Vorsatz et al. 2013, p. 734): "*Retrofitting existing buildings is a discretionary investment – no action is an option, and often an easier option. Building owners and occupiers therefore need to be persuaded not only of the merits of energy investment, but to finance it and bear whatever disruption it entails"* Wilsen et al. (2015) designed a model to demonstrate how incorporating applied behavioural research on energy efficiency can enhance an instrumental understanding of why homeowners decide to renovate energy efficiently. This study aims to apply their model to the investment behaviour of Dutch homeowners and assess the impact of behavioural factors on investment decisions. To achieve this, the study will review empirical literature on the variables associated with each factor to analyse their influence on investment behaviour.

2.2 Motivations

According to Wilsen et al. (2015), motivational factors play a crucial role in homeowners' behaviour regarding energy efficiency investments. In fact, the presence of a motivational factor is a dominant predictor of whether homeowners will undertake renovation projects (Jakob, 2007). However, motivation, which refers to the intention and willingness to act, must be encouraged before actual action is taken (Grothmann and Reusswig, 2006). Initial studies on homeowners' behaviour focused solely on the financial benefits of investment, as conservation technologies yield monetary benefits by reducing energy costs. Gates (1983) notes that conserving energy may be one of the most rewarding investments a homeowner could make. His research on conservation behaviour indicates that EEMs have significantly higher rates of return than alternative investments in stocks, bonds and real estate. Nevertheless, the adoption of EEMs is inconsistent with these high yields, as noted by Howarth and Andersson (1993). They argue that consumers should base their investment decisions on perceived prices and expectations of equipment performance, with cost savings as their primary motivation. Nonetheless, conducting an accurate cost-benefit analysis can be difficult and expensive, resulting in differences between expected and actual cost savings (Howarth and Andersson, 1993). Consequently, homeowners may decide not to invest in energy efficiency measures. Such market barriers result in what Gates (1983) calls the energy paradox.

Investments in EEMs serve not only an economic purpose, but also non-economic purposes, such as increased comfort and convenience (Mahapatra and Gustavsson, 2008; Zundel and Stieß, 2011).

For instance, the implementation of a new heating system, insulation of walls or replacement of windows can all lead to lower energy consumption. At the same time, they provide comfort benefits, including higher indoor air quality, increased thermal comfort and reduced noise pollution (Jakob, 2006).

Another reason why homeowners opt for energy-efficient renovations, is when they are already necessary, often due to a building element reaching the end of its useful life or experiencing damage. This frequently occurs in houses built a few decades ago, leading to renovations that also serve as an impetus for energy efficiency improvements, as more advanced insulation materials are used (Jakob, 2007).

Finally, environmental awareness can also serve as a motivation for homeowners to invest, but it is typically considered a lower priority compared to other motivational factors (Nair, 2010). This is because changes in energy efficient behaviour seem to be realistic only when trends in lifestyle, energy-efficiency measures and behaviour coincide (Lindén et al. 2006). Having the environment as motivation represents a lifestyle change that may not be identified with a reduced quality of life or social status, which can render this motivation ineffective in the presence of large costs or significant barriers (Held, 1983; Pellegrini-Masini et al. 2010). However, those who prioritize environmental concerns are more likely to invest in EEMs with the highest energy efficiency outcomes, making it one of the most significant motivational factors (Martinsson et al. 2011).

2.3 Contextual factors

Social scientists emphasize that motivational factors alone do not guide the adoption of EEMs, as personal and contextual factors also play a crucial role. Income is has been identified as a dominant contextual factor for predicting investment behaviour, as demonstrated by the academic literature (Held, 1983). Research by Ritchie et al. (1981) support this finding, demonstrating that an increase in household income leads to higher energy use. However, the relationship between household income and investment in EEMs remains a topic of debate. With the objective to identify the factors influencing daily energy-saving behaviours and on the adoption of energy efficient measures by British households, Trotta (2018) found a direct positive relationship between household income and the probability of investing in EEMs. Additionally, he shows that households with medium and high incomes are more likely to invest in high-cost EEMs, not only because their financial capacity, but also because they consistently consume more energy and thus have more incentives to benefit from EEMs (Urban and Ščasný, 2012; Wiedenhofer et al. 2011). However, case studies in Sweden and Ireland of Jakob (2006) and Aravena et al. (2016) respectively found no significant effect between household income and the adoption of EEMs. Given the conflicting results from these studies, it is difficult to predict the effect of income on Dutch households' investment decision.

Another contextual factor that affects a homeowner's decisions-making process is the level of energy price inflation. Many researchers have highlighted the significance of energy prices on household energy-saving behaviour. For example, Long (1993) analysed survey data of US homeowners to examine the effectiveness of incentives in promoting household energy conservation behaviour. His statistically significant results show a 0.21 percentage point increase in conservation investments for every increasing percentage point in energy costs. This is because potential savings become more valuable when energy prices are expected to rise (Gates, 1983). In a conjoint choice experiment conducted by Alberini et al. (2013), Swiss homeowners were surveyed about their preferences for energy efficiency home renovations. Their results indicate that homeowners' expectations of future energy prices play an important role in their investment decision. Respondents who are uncertain about future energy prices tend to prioritize costs over financial gains and are less likely to invest. Dillman et al. (1983), examined the extent to which higher energy prices lead to lifestyle cutbacks in expenditure areas for US homeowners. They reveal that not all household are financially able to hedge against energy inflation. Consequently, wealthier households are more likely to invest in EEMs, while poorer households are forced to cut back on all their expenditures to cope with increased energy prices.

In addition to household income and energy price inflation the investment decision can also be influenced by government subsidies. Empirical research shows ambiguous results for incentive initiatives, such as subsidies for the purchase of insulation, tax credits for solar equipment and low interest loans for the purchase of heat pumps (Sardianou, 2007). For instance, some researchers, including Pitts & Wittenbach (1981), have found no direct relationship between the existence of federal tax credit and energy efficiency improvements. Other researchers, like Walsh (1989), found evidence that energy tax credits do not lead to an increase in investments in energy efficiency. However, Long (1993) shows that homeowners spend more on EEMs when these investments are subsidized by government tax policies. Cameron (1985) also supported this finding. By analysing the effect of various policy measures on the medium-run adjustments to the existing housing stock, she found that a 1% increase in government subsidization, covering 15% of conservation costs, would encourage an additional 0.2% of homeowners to invest in EEMs. The variability in results among empirical research makes it challenging to draw conclusions about the impact of energy tax credits on homeowners' investment behaviour. However, the variability in the results can be explained by the research conducted by Bruel and Hoekstra (2005). They found that the existence of government tax subsidies has different outcomes based on the income classification of homeowners. Their results show that lower-income households are more responsive to subsidies and advice on reducing energy bills, while higher-income households are more influenced by personalised advice and calls to improve comfort and social responsibility.

2.4 Personal factors

Personal factors, such as age, education, household type and number of occupants, can also impact the investment behaviour of homeowners. These factors can influence the energy consumption and energy savings potential of a home, as well as the perceived benefits and costs of EEMs. Various studies have explored the relationship between age and energy conserving behaviour. By studying survey data compiled for the US Department of Energy, Walsh (1989) found that older persons are less likely to invest in EEMs because they expect a relatively lower rate of return than other age cohorts. Results of

Nair et al. (2010B) are in line with the findings of Walsh (1989). By drawing on survey data of Swedish homeowners of detached houses, they analyse the factors that influence the adoption of EEM investments. Their results also indicate that younger homeowners are more likely to invest. However, even though homeowners in the age group of 36-45 are more likely to adopt EEMs, homeowners above the age of 65 are more likely to invest in high-cost EEMs. The majority of the older respondents made an investment between 5,000 and 25,000 SEK (approximately 450 – 2,300 Euro). Hirst an Goeltz (1982) found a curvilinear relationship between age and conservation behaviour, with young and elderly households to be less likely to invest. They clarified that older persons are less likely to adopt EEMs due to factors as decayed insulation, diminished physical ability, less formal education and a lack of energy knowhow.

Numerous studies have analysed the connection between education and energy-saving behaviour, with the majority of findings indicating a positive correlation. Mills and Schleich (2012) focused on household energy efficiency in the EU and discovered that individuals with a university degree are more likely to invest in EEMs. In addition, Nair et al. (2010B) found that homeowners who had only completed primary education tend to undertake only non-investment measures, while those with a secondary education were more inclined to adopt high-cost investments. However, the level of education has no significant influence neither on the number of energy conservation actions (Curtis et al., 1984) nor on actual energy consumption (Ritche et al., 1981). One possible explanation for the positive association is that education lowers the cost of acquiring information (Schultz, 1975)

According to Huebner et al. (2015), the household and property characteristics account for the majority of the variance in energy consumption. Their study examines to the extent to which household- and property related variables can explain annualized energy consumption in English households. The researchers found that property characteristics have the highest explanatory power, accounting for approximately 39% of the variability. This finding is consistent with the results of Van den Brom et al. (2019), who aimed to determine the proportion of heating consumption variance in Dutch and Danish households attributable to occupants versus building characteristics. they found that property characteristics explain half of the variance. According to Wilson et al. (2015) variables describing household and property characteristics are household size, building type and building year. Curtis et al. (1984) found that households with two to four people tended to take more actions towards in-home energy consumption compared to households with different sizes. By employing cross-section data, Sardianou (2007) developed an empirical model to investigate the main determinants of energy conservation patterns of Greek households. At a significance level of 1%, his findings indicate that household energy conservation behaviour increases as the number of occupants increases. Additionally, his results show that the number of rooms and fitted square area are not significant determinants of energy efficiency behaviour, but households residing in detached houses are more inclined to engage in energy conservation activities than those living in apartment blocks. The study also found that owners of houses over 25 years old are most likely to invest in high-cost EEMs (Stieß & Dunkelberg, 2013)

In summary, empirical research shows that homeowner's investment behaviour towards EEMs is the result of motivational-, contextual- and personal factors. Motivational factors create the intention and willingness to invest in EEMs and are represented by cost saving, comfort gains, the necessity to renovate and environmental awareness. Among contextual factors, income, energy price inflation and the provision of subsidies have been identified as dominant factors for predicting investment behaviour. Personal factors can be described by age, education level, household size, building type and building year (Table 1). Because the impact of these factors differ among countries, empirical results cannot be generalised to the Netherlands. They rather serve as an indication of significant factors that should be included in the conceptual model.

Table 1*: Explanatory variables of investment behaviour*

Motivational factors	Contextual factors	Personal factors
Cost saving	Gross income	Age
Comfort gains	Energy price inflation	Education level
The necessity to renovate	Subsidy	Household size
Environmental awareness		Building type
		Building year

2.6 Qualitative expectations

Drawing on the existing empirical literature, it is possible to formulate assumptions about the characteristics of the relationship between the variables and investment behaviour prior to undertaking model estimation. For the motivational factors, academic literature suggests that it is a dominant predictor when homeowners decide to invest (Jakob, 2007). Moreover, the motivational factor also affects the efficiency level of the investment. For instance, homeowners investing due to environmental concerns are more likely to invest in EEMs with the highest energy efficiency outcomes (Martinsson et al., 2011).

For the contextual factors, gross income is identified as a key predictor of investment behaviour, as indicated by Held (1983). Trotta (2018) anticipates a positive coefficient for households with medium and high incomes, who are more likely to invest in high-cost EEMs. However, the relationship between subsidies and investment behaviour is not straightforward, as empirical studies yielded mixed results. While Pitts & Wittenbach (1981) found no direct relationship, Walsh (1989) observed that energy tax credits do not lead to an increase in EEM investments. Conversely, the results of Cameron (1985) show a positive association, underscoring the importance of including this variable in the model. If the results reveal a significant relationship, a positive coefficient is expected, as demonstrated by Long's (1993) research, which indicates that homeowners tend to spend more on EEMs when government tax policies offer subsidies.

The personal factors incorporated into the model are age, education, household size, building type and building year. Walsh (1989) discovered that individuals above the age of 65 tend to invest the most in high-cost EEMs, while and Nair et al. (2010B) added that younger age groups are the most inclined to adopt EEMs. Education level, as indicated by Curtis et al. (1984) and Ritchie et al. (1981), has no significant impact on the number of energy conservation actions or actual energy consumption. Nevertheless, Nair et al. (2010B) found that homeowners with secondary education tend to adopt high-cost investments, while those with primary education tend to undertake only non-investment measures. In accordance with Sardianou's model (2007), the number of occupants in a household is positively correlated with energy conservation activities. Moreover, Sardianou's (2007) findings indicate that homeowners residing in detached houses are the most likely to invest. Lastly, Stieß & Dunkelberg (2013) observed that owners of houses older than 25 years are most likely to invest in high-cost EEMs .

Thus, with regards to the likelihood of a homeowner to invest, it is hypothesized that environmental awareness, augmented household size, and the ownership of detached houses serve as influential determinants. Furthermore, the presence of subsidies may also increase the likelihood of homeowners to invest in EEMs. However, the uncertain and inconclusive nature of the empirical research findings poses challenges in definitively affirming this relationship. Concerning the factors influencing the magnitude of the investment, it is hypothesized that an elevation in gross household income, advancing age, older building years, as well as higher levels of education contribute to greater levels of EEM investments.

3. Data

In order to answer the research question in a quantitative manner, this study utilizes a publicly available dataset. This chapter provides information about the selected dataset, expounds upon the data cleaning procedure, presents a thorough analysis of the sample's characteristics, and introduces the conceptual model.

3.1 Dataset overview and representativity

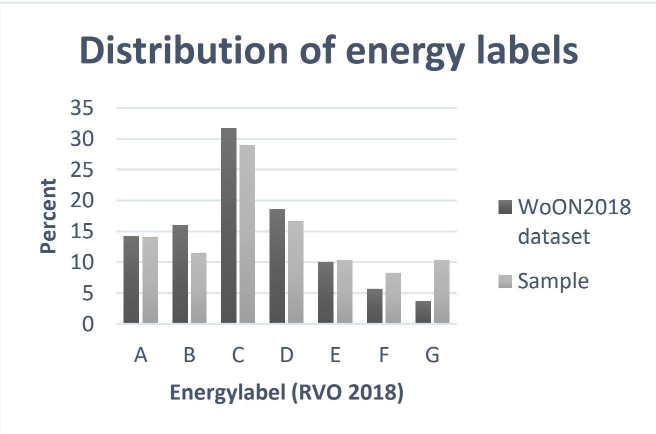
This study utilizes two datasets compiled by Statistics Netherlands, namely the Netherlands' Housing Survey (WoON) and the WoON Energymodule. The Housing Survey, conducted every three years since 2006, provides insights into the composition of Dutch households, housing situations, housing requirements, housing costs and relocation behaviour. The WoON data are collected through a sample survey of all non-institutionalised Dutch residents aged 18 or older and registered at their local municipality. From this group, a stratified sample is taken, resulting in over 67,000 respondents, with nationwide coverage of municipalities. The survey data are supplemented with administrative data.

In addition, the study uses the WoON Energymodule, a follow-up dataset of the Housing survey, collected through a survey and a technical survey of the houses. Approximately 4,500 households from the population of the Housing survey form the sample of the Energymodule. This survey collects information on the energy quality of the Dutch housing, the energy consumption, energy behaviour of households, and their investment behaviour concerning EEMs.

This study utilizes the 2018 datasets despite the more recent WoON Housing dataset being from 2021, as the corresponding Energymodule is not yet available. The two datasets are merged because the Housing Survey includes the motivational factors and the gross income of the homeowners, which empirical research has shown to be important factors in studying investment behaviour. The Energymodule includes the other variables of interest.

The WoON Energy-module is the primary dataset utilized in this study, comprising 4,506 dwellings, of which approximately 64% (2,878) belong to the owner-occupied sector. After excluding all respondents from the rental sector, the dataset underwent further refinement based on the investment amounts of the homeowners. Firstly, those homeowners who invested but did not disclose or know their investment amount are excluded. Secondly, investments below €500.- are considered insignificant and are therefore excluded based on the study of Ebrahimigharehbaghi et al. (2022) using the same dataset. Lastly, two respondents are excluded, one who invested €480,000, as it is perceived as a reconstruction rather than an EEM installation, and another who reported a negative income. After the data cleaning process, the resulting sample comprised 1,771 respondents, of which 708 have invested in EEMs. To ensure the representativeness of the reduced sample and thereby the reliability of the study, the sustainability levels of the houses are compared based on energy labels with that of the total population of the Housing Survey. The disparity in the distribution of the energy labels between the Housing Survey and the study sample is shown in Figure 1. Notably, the most significant differences are the underrepresentation of energy label B by 4.66 percent points and the overrepresentation of energy label G by 6.70 percent points. A potential reason for this inconsistency is that the energy labels in the Housing dataset rely on register data collected by the government, whereas the labels in the Energy module depend on the homeowners' self-reported energy labels, due to a lack of adequate public data for the sample.

Figure 1: *Sustainability level of sample data*



3.2 Descriptive statistics

Based on the literature review, the variables of interest are categorized into motivational-, contextual-, and personal factors. For the motivational factors, the WoON survey provided the respondents with seven options to elucidate the reason why homeowners have invested or would invest in EEMs. However, only four motivational factors explain the majority of the intention and willingness to invest. The primary motivation for homeowners of the sample to invest is the need for renovation. Additionally, the ability of the investment to pay for itself through lower energy costs and an increase in comfort are also significant motivational factors. Finally, approximately twelve percent of homeowners invest in EEMs owing to environmental concerns (Table 2). However, among those who have already made investments, the majority were driven by the motivation of cost savings (Appendix I, Table 5). These motivational factors align with those identified in the empirical literature. Regarding the contextual factors, the average gross household income of the sample in 2017 is approximately € 78,690. On average, respondents who invested in EEMs due to environmental concerns have the highest gross household income, while those who invest because of necessary renovations exhibit the lowest (Appendix I, Table 7). Around a quarter of the investors received incentive initiatives. Because the dataset is not longitudinal, is does not include energy price inflation. For the personal factors, the majority of respondents belong to the age group of 65-74, with the number of respondents decreasing for each younger age group. The educational level of the respondents is categorized into three levels: low, middle and high, with low being elementary school graduates, middle being high school graduates, and the highest level being possessed by the majority of respondents (54%). In terms of household size, over half of the households have two occupants. The property characteristics show that most homeowners live in townhouses, and the majority of the houses were constructed before 1945. To evaluate the impact of these factors on the amount homeowners allocate to the investment, respondents who invested in EEMs within the past five years were asked to report their spending exclusively on EEMs. On average, homeowners spent € 6,168 during the period from 2013 to 2018. When controlling for motivational factors, those investing to increase comfort exhibit the highest average investments, whereas those who invested to saving energy costs have the lowest average investments (Appendix I, Table 8).

__Table 2__: Summary statistics of behaviour influencing factors

Variable	Categories	Frequency	Percent	Mean	Std. dev.
Invested in EEMs		708		6,168.182	7,980.518
Ln(Invested in EEMs)		708		8.252	0.959
Gross income		1,721		78,690.59	47,693.97
Motivation to invest in EEMs	Due to maintenance	553	32.13		
	To save energy costs	492	28.59		
	To improve comfort	379	22.02		
	For the environment	200	11.62		
Subsidy	Yes	182	10.58		
	No	1,482	86.11		
Age	25 – 34	131	7.61		
	35 – 44	218	12.67		
	45 – 54	266	15.46		
	55 – 64	461	26.79		
	65 – 74	488	28.36		
	>75	154	8.95		
Education	Low	312	18.13		
	Middle	472	27.43		
	High	923	53.63		
Household size	1	347	20.16		
	2	874	50.78		
	3	180	10.46		
	4	221	12.84		
	5 (+)	99	5.75		
Household type	Apartment	244	14.18		
	town home	696	40.44		
	Semi-detached home	344	19.99		
	Detached home	411	23.88		
Building year	Before 1945	380	22.08		
	1945 – 1959	128	7.44		
	1960 – 1969	170	9.88		
	1970 – 1979	374	21.73		
	1980 – 1989	264	15.34		
	1990 – 1999	245	14.24		
	2000 – 2009	125	7.26		

3.3 Methodology

The aim of this research is to examine the factors that determine the likelihood of a homeowner to invest, and to identifying the factors that impact the magnitude of the investment. To achieve this objective, two distinct regression models will be employed. To address the first hypothesis, a probit regression model will be utilized to identify the factors that increases the likelihood of a homeowner investing in EEMs. Due to the binary nature of the dependent variable in the analysis, specifically classified as "invested" or "not invested", a probit model will be utilized as it is more suitable than linear regression model. Furthermore, the utilization of a probit regression is advantageous over a logit regression when addressing binary outcomes, as it provides estimates in terms of probabilities rather than the raw response values. This allows for a more intuitive interpretation of the results. In the context of this analysis, the contextual factor "subsidies" is not incorporated into the regression model. This is due to the fact that subsidies are provided by the investment itself and are not yet allocated during the decision-making process. This results in the following regression equation:

$$\begin{aligned} Invested\ (yes/no) \\ &= \beta_0 + \beta_1 Motivation + \beta_2 Gross.income + \beta_3 Age + \beta_4 Education \\ &+ \beta_5 Household.size + \beta_6 Building.type + \beta_7 Building.year + \epsilon \end{aligned}$$

To address the second hypothesis, a linear regression model will be employed to identifying the factors that impact the magnitude of the investment, among homeowners who have already invested in EEMs. However, since the amount invested by homeowners is not distributed normally, as shown in Appendix II, Figure 2, the linear regression model uses the natural logarithm of the amount invested as the dependent variable. This transformation results in a more normal distribution of data, as illustrated in Appendix II, Figure 3. Consequently, the resulting regression equation is as follows:

$$\begin{aligned} \log(amount\ invested\ (€)) \\ &= \beta_0 + \beta_1 Motivation + \beta_2 Gross.income + \beta_3 Subsidy_i + \beta_4 Age \\ &+ \beta_5 Education + \beta_6 Household.size + \beta_7 Building.type + \beta_8 Building.year + \\ &\epsilon \end{aligned}$$

The parameters β_x provide information about the effect of the variables on the dependent variable. Except β_0, which represents the formula's constant. The ϵ at the end of the formula represents the stochastic error.

4. Results

Chapter 4 presents the study's result. Firstly, table Table 3 presents the results of the probit regression, which shows which factors increases the likelihood of a homeowner to invest in EEMs . Secondly table Table 4 presents the outcomes of the log-linear relationship between the amount invested in EEMs and the behaviour influencing factors. Thereafter, the outcomes are discussed extensively by connecting them to empirical studies and the expectations formulated in chapter 2.

4.1 Probit regression results

The aim of the probit regression analysis is to examine the factors that influence the likelihood of a homeowner investing in energy efficiency measures. In the model, each coefficient indicates the direction and strength of the relationship between the variable and the likelihood of the homeowner to invest in EMMs, holding all other variables constant. The chi-squared test suggests that the model, as a whole, is statistically significant, meaning that at least one of the independent variables has a significant effect on the likelihood of the investment. The R-squared value of 0.0755 suggests that the model explains only a small proportion of the variation in the dependent variable.

In terms of the specific coefficients, the regression analysis results reveal that the motivational factors exert the strongest positive effect on the investment decision. With homeowners investing since renovation was already necessary serving as the reference category, homeowners investing due to environmental concerns have the highest probability of investing, with a coefficient of 0.564 ($z = 5.83$, $p = 0.000$), followed by those who invest to save money with a coefficient of 0.484 ($z = 5.83$, $p = 0.000$). Concerning the personal factors, age and building type significantly affect the likelihood to invest. The probability of investing in EEMs decreases as age increases, with the oldest age group exhibiting the strongest negative effect with a coefficient of -0.648 ($z = -4.06$, $p = 0.000$). Building type is positively associated with investing in EEMs, with detached houses having the strongest effect with a coefficient of 0.496 ($z = 4.07$, $p = 0.000$). Among the contextual factors, only household income is included in the model, which does not show a significant relationship with the likelihood to invest. Overall, the regression results suggest that motivational factors, the homeowner's age and building type have the most substantial influence on the investment decision.

As a test of the model's robustness, the goodness-of-fit test evaluates how well the model fits the data. The Pearson chi-squared test statistic, which has a value of 1735.65 with 1688 degrees of freedom, has an associated p-value of 0.2050 (Appendix III, Table 9). A non-significant p-value indicates that the model fits the data well and is not significantly different from the observed data. However, it should be noted that this test only evaluates the overall fit of the model and does not provide insight into the validity of individual predictors or omitted variables.

Table 3: *Probit regression model on the likelihood to invest*

Category	Variables	Coefficients	Invested
Motivational factor	Motivation	Due to maintenance	
		To save money	0.484
			(0.083)***
		For comfort	0.292
			(0.089)***
		For the environment	0.564
			(0.110)***
Contextual factors	Gross income		0.003
			(0.007)*
Personal factors	Age	25 – 34	
		35 – 44	-0.335
			(0.765)**
		45 – 54	-0.406
			(0.143)***
		55 – 64	-0.556
			(0.137)***
		65 – 74	-0.554
			(0.140)***
		>75	-0.648
			(0.168)***
	Education	Middle	
		Low	-0.200
			(0.099)*
		High	0.062
			(0.077)
	Household size	1	
		2	0.175
			(0.092)*
		3	0.197
			(0.132)
		4	0.099
			(0.135)
		5 (+)	0.095
			(0.171)
	Building type	Apartment	
		town home	0.403
			(0.113)***
		Semi-detached home	0.457
			(0.124)***
		Detached home	0.496
			(0.122)***
	Building year	Before 1945	
		1945 – 1959	-0.191
			(0.135)
		1960 – 1969	0.002
			(0.121)
		1970 – 1979	-0.054
			(0.098)
		1980 – 1989	-0.032
			(0.107)
		1990 – 1999	-0.296
			(0.111)***
		2000 – 2009	-0.344
			(0.140)*
	Constant		-0.536
			(0.170)***
	Observations		1,772
	Log likelihood		-1077.759

*The dependent variable is whether the homeowner has invested in energy efficiency measures or not. The reference category for the invested amount is the first coefficient of every variable (blanks). Standard errors in parentheses with ***, **, *, indicating significance at 1%, 5% and 10% respectively.

4.2 Linear regression results

After identifying the factors that influence the likelihood of a homeowner investing in energy efficiency measures, the second model aims to examine how these factors impact the amount of capital allocated to EEMs. Therefore, this model only includes homeowners of the sample that actually have invested. The output of the linear regression model illustrates the associations between motivational-, contextual-, and personal factors and the dependent variable, which represents the natural logarithm of the invested amount in EEMs. The regression analysis shows that the model is statistically significant ($F(34,673) = 2.78$, $p = 0.000$). However, the R-squared value (0.1233) indicates that the model only explains 12.33% of the variance in the dependent variable (Table 4).

The regression results show that the majority of the motivational- and personal factors have no significant impact on the amount of capital homeowners invest in EMMs, with the except of building type. Homeowners living in detached houses have a positive coefficient of 0.056 ($t = 4.09$, $p = 0.000$), at the 1% level of significance, implying that they tend to invest more in EEMs than homeowners in other types of houses. The contextual factors explain most of the variability of the invested amount in this model. Gross household income has a positive coefficient of 0.006 ($t = 3.35$, $p = 0.001$) at a 1% significance level, indicating that an increase in household income is associated with higher investments in EEMs. Additionally, the presence of subsidies has a coefficient of 0.213 ($t = 2.07$, $p = 0.039$) and is significant at a 5% level, suggesting that the invested amount increases when homeowners receive subsidies on their investment.

To verify the robustness of the linear regression model, the variance inflation factor (VIF) analysis assesses multicollinearity among the predictor variables. When multicollinearity occurs, the independent variables correlate which can lead to skewed or misleading results. Most of the VIF values are below 2 with a mean VIF-value of 1.83 (Appendix III, Table 10), which is generally considered low and suggests that multicollinearity is not observed.

Table 4: *Log-linear regression model of the amount invested*

Category	Variables	Coefficients	Ln(euro's invested in EEMs)
Motivational factor	Motivation	Due to maintenance	
		To save money	0.025 (0.098)
		For comfort	0.110 (0.105)
		For the environment	0.142 (0.124)
Contextual factors	Gross income		0.006 (0.007)***
	Subsidy	No	
		Yes	0.179 (0.086)**
Personal factors	Age	25 – 34	
		35 – 44	-0.041 (0.150)
		45 – 54	-0.208 (0.148)
		55 – 64	-0.168 (0.142)
		65 – 74	-0.031 (0.146)
		>75	-0.196 (0.187)
	Education	Middle	
		Low	0.038 (0.117)
		High	-0.034 (0.085)
	Household size	1	
		2	0.005 (0.111)
		3	0.049 (0.146)
		4	-0.022 (0.149)
		5 (+)	0.063 (0.188)
	Building type	Apartment	
		town home	0.228 (0.144)
		Semi-detached home	0.258 (0.157)
		Detached home	0.631 (0.154)***
	Building year	Before 1945	
		1945 – 1959	0.164 (0.151)
		1960 – 1969	0.018 (0.128)
		1970 – 1979	0.152 (0.106)
		1980 – 1989	-0.104 (0.116)
		1990 – 1999	-0.232 (0.128)*
		2000 – 2009	0.083 (0.161)
	Constant		7.703 (0.189)***
	Observations		696
	R-squared		0.093

*The dependent variable is the natural logarithm of euro's invested in energy efficiency measures. The reference category for the invested amount is the first coefficient of every variable (blanks). Standard errors in parentheses with ***, **, *, indicating significance at 1%, 5% and 10% respectively.

4.3 Model results

To evaluate the outcomes, this section compares the findings of this study with previous empirical research and the pre-regression model expectations. Firstly, the motivational factors significantly influence the investment decision. As hypothesized, the homeowner's intentions and willingness to invest are crucial determinants of the likelihood of investing in energy efficiency measures, with environmental concerns being the strongest predictor. This finding is consistent with the results of Martinsson et al. (2011), which demonstrate that individuals with environmental concerns prefer investments in EEMs that yield higher energy efficiency benefits. The decrease in the likelihood of investing when homeowners aim to reduce energy costs may be due to cost-benefit analysis barriers, as explained in Gates'(1983) energy paradox. The investment decision is also influenced by the age of the homeowner. Walsh (1989) argues that the reason why older homeowners are less likely to invest in EEMs is because of their lower expected rate of return. However, findings slightly deviate from those of Nair et al. (2010B), as this study found that the 25-34 age group is most likely to invest, rather than the 36-46 age group. Additionally, Sardianou's (2007) research shows that households residing in detached houses are more willing to engage in energy conservation activities, explaining the significant positive effect of detached houses on both the likelihood of investing and the invested amount. Furthermore, his work indicates that the number of occupants in a household positively correlates with the engagement in energy conservation activities. However, neither of the regression models in this study reveal a significant relationship for the variable household size.

Regarding the magnitude of the investment, the contextual factors have the greatest impact. Unlike the case studies conducted by Jakob (2006) and Aravena et al. (2016), this study aligns with the empirical studies of Trotta (2018) and Ritchie et al. (1981), indicating a positive relationship between household income and conservation behaviour. Researchers suggests that this positive relationship is not only due to financial capability, but also because households with higher income consume more energy and therefore have greater incentive to benefit from EEMs (Urban and Ščasný, 2012; Wiedenhofer et al., 2011). According to Long (1993), homeowners spend more on EEMs when these investments are subsidized by government tax policies. While other empirical research has produced conflicting results, this study provides support for Long's findings by demonstrating a significant positive relationship between government tax policies and the amount invested. The findings of Nair et al. (2010B) that homeowners over the age of 65 and those with secondary education invest more in high-cost investments are not supported by this study, as the model shows no significant relationship between the age or education level of the homeowner and the amount invested.

5. Conclusion

5.1 Main results

The present study analyses Dutch homeowners investment behaviour, by examining the factors that drive homeowners to invest in EEMs and by investigating the impact of these factors on the magnitude of their investments. The study yields noteworthy findings concerning the effect of motivational-, contextual-, and personal factors on investment behaviour. The motivational factors emerge as strong predictors of the investment decision, along with the homeowner's age and building type, influencing the likelihood of a homeowner to invest in EEMs. When a homeowner decides to invest, the personal factors explain most of the variability in the investment amount, with higher gross household income and the presence of subsidies leading to greater investments. Additionally, owners of detached houses also tend to spend more on EEMs.

5.2 Limitations and further research

This study encountered various constraints that affected the investigation of investment behaviour among Dutch homeowners. Firstly, the small sample size limits the generalizability of the findings. Secondly, the absence of the latest WoON energy module from 2021 restricted access to recent data. Homeowners' motivations for investing in EEMs may have changed over time due to the increasing awareness of climate change and higher energy prices. Moreover, the lack of a longitudinal dataset precluded the testing of the effect of energy price inflation on investment behaviour. As empirical studies have demonstrated energy price inflation as a significant driver, the absence of this variable may account for the low R-squared value of the regression model. Finally, the use of self-report surveys for data collection may have introduced response bias or social desirability bias.

Despite these limitations, this study provides valuable insights into the factors that influence homeowners' decisions to invest in energy efficiency measures. Future research could expand upon these findings in several areas. Firstly, increasing the sample size could further investigate the effect of the significant relationships. Secondly, longitudinal datasets could be employed to examine the impact of energy price inflation on investment behaviour. Finally, cross-country comparative studies could be conducted by incorporating datasets that encompass homeowners from diverse backgrounds. By employing such an approach, differences in the results would not stem from variations in research design, thus rendering them more reliable than comparing different case studies.

5.3 Policy implications

The results of this study hold important policy implications for promoting investments in Energy Efficiency Measures (EEMs) among Dutch homeowners and achieving emission reduction targets within the real estate sector. The following policy recommendations can be drawn from the findings:

Increasing Environmental Awareness: Policymakers should prioritize efforts to raise awareness of environmental issues among homeowners. Emphasizing the environmental benefits and long-term sustainability of EEMs can significantly influence homeowners' likelihood to invest in energy-efficient measures. Educational campaigns, public outreach programs, and information dissemination initiatives can be implemented to enhance homeowners' understanding of the environmental impact of their choices.

Subsidy Programs: The study highlights a significant and positive relationship between subsidies and the amount invested in EEMs. Policymakers should consider designing and implementing effective incentive programs, such as financial subsidies or tax incentives, to encourage homeowners to adopt energy-efficient practices. Well-designed subsidy schemes can offset the upfront costs associated with EEMs and provide the necessary financial support to facilitate widespread adoption.

Targeted Approach for Non-Detached Houses: The study reveals that homeowners residing in non-detached houses exhibit lower EEM investments. Therefore, policymakers should pay particular attention to this segment of homeowners and develop tailored strategies to address their specific barriers and concerns. This may involve targeted financial incentives, customized educational campaigns, or policy measures that specifically address the unique challenges faced by non-detached homeowners in adopting energy-efficient measures. At the same time, it is imperative to devote further research efforts to understand the underlying reasons for their lower investment propensity.

By incorporating these policy implications, policymakers can create a supportive environment that encourages homeowners to invest in EEMs, reduces energy consumption, and facilitates the transition towards a more sustainable and environmentally friendly housing sector in the Netherlands.

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Appendix

Appendix I

Table 5: *summary statistics of investors*

Variable	Categories	Frequency	Percent	Mean	Std. dev.
Invested in EEMs		708		6,168.182	7,980.518
Ln(Invested in EEMs)		708		8.252	0.959
Gross income		708		84,825.07	50.442.57
Motivation to invest in EEMs	Due to maintenance	171	24.15		
	To save energy costs	240	33.90		
	To improve comfort	164	23.16		
	For the environment	106	14.97		
Subsidy	Yes	182	25.71		
	No	515	72.74		
Age	25 – 34	71	10.03		
	35 – 44	99	13.98		
	45 – 54	118	16.67		
	55 – 64	183	25.85		
	65 – 74	186	26.27		
	>75	49	6.92		
Education	Low	98	13.84		
	Middle	193	27.26		
	High	415	58.62		
Household size	1	107	15.11		
	2	364	51.41		
	3	86	12.15		
	4	104	14.69		
	5 (+)	47	6.64		
Household type	Apartment	61	8.62		
	town home	299	42.23		
	Semi-detached home	146	20.62		
	Detached home	187	26.41		
Building year	Before 1945	175	24.72		
	1945 – 1959	49	6.92		
	1960 – 1969	78	11.02		
	1970 – 1979	164	23.16		
	1980 – 1989	114	16.10		
	1990 – 1999	81	11.44		
	2000 – 2009	43	6.07		

Table 6: *Gross household income per motivational factor of sample*

Motivation to invest	Obs.	Mean	Std. dev.	Min	Max
Due to maintenance	553	75,381.40	40,668.08	7,098	453,651
To save energy cost	492	79,151.54	47,879.33	10,755	404,509
To improve comfort	379	77,995.32	49,320.40	11,783	509,573
For the environment	200	93,468.20	55,843.12	14,706	451,236

Table 7: *Gross household income per motivational factor of investors*

Motivation to invest	Obs	Mean	Std. dev.	Min	Max
Due to maintenance	171	77,700.21	35,923.05	8,730	238,790
To save energy costs	240	83,180.79	45,085.47	17,403	324,857
To improve comfort	164	83,329.47	58,556.26	11,783	509,573
For the environment	106	101,736.90	62,067.42	20,879	451,236

Table 8: *amount invested in EEMs per motivational factor*

Motivation to invest	Obs.	Mean	Std. dev.	Min	Max
Due to maintenance	171	6,177.04	9,573.24	500	70,000
To save energy cost	240	5,417.92	5,089,75	500	40,000
To improve comfort	164	6,899.21	7,862.71	500	50,000
For the environment	106	6,035,19	5,138.23	500	35,000

Appendix II

Figure 2: *Distribution of amount invested in EEMs*

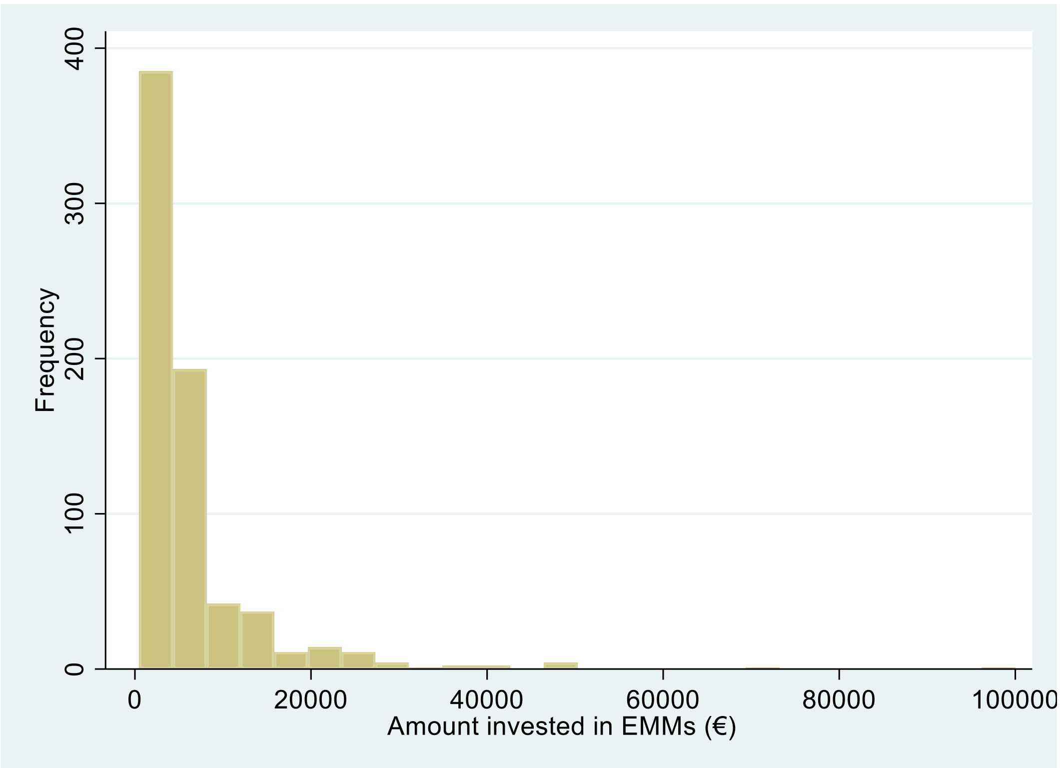
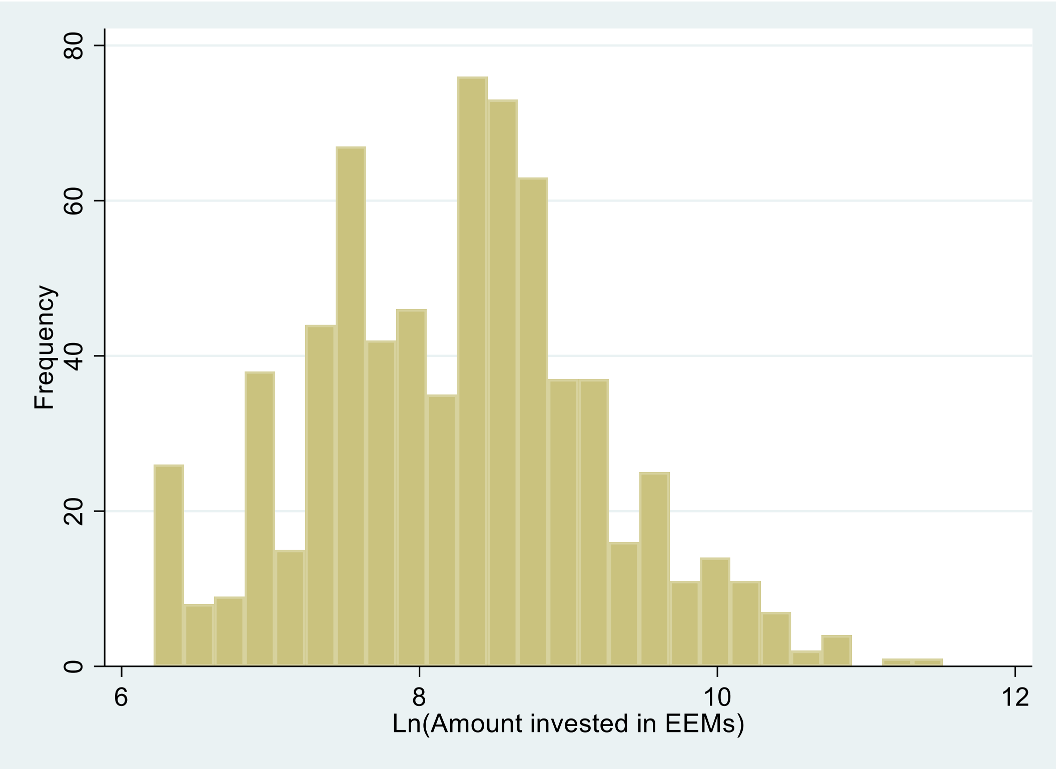


Figure 3: *Distribution of the natural logarithm of the amount invested in EEMs*



Appendix III

Table 9: *Robustness check probit regression model*

Goodness-of-fit test after probit model	
Number of observations	1,721
Covariate patterns	1,721
Pearson Chi2(1688)	1,735.65
Prob > Chi2	0.2050

Table 10: *Robustness check linear regression model*

Variable		VIF	1/VIF
Motivation	Due to maintenance		
	To save money	1.80	0.555
	For comfort	1.63	0.615
	For the environment	1.64	0.610
Gross income		1.29	0.776
Subsidy	No		
	Yes	1.19	0.838
Age	25 – 34		
	35 – 44	2.26	0.442
	45 – 54	2.53	0.396
	55 – 64	3.25	0.308
	65 – 74	3.46	0.289
	>75	1.88	0.531
Education	Middle		
	Low	1.35	0.739
	High	1.48	0.675
Household size	1		
	2	2.57	0.389
	3	1.90	0.525
	4	2.34	0.428
	5 (+)	1.83	0.546
Building type	Apartment		
	town home	3.37	0.238
	Semi-detached home	3.37	0.297
	Detached home	3.86	0.259
Building year	Before 1945	1.23	0.813
	1945 – 1959	1.35	0.739
	1960 – 1969	1.67	0.599
	1970 – 1979	1.53	0.653
	1980 – 1989	1.39	0.717
	1990 – 1999	1.24	0.809
	2000 – 2009	1.06	0.943
	Mean VIF	1.83	