MASTER'S THESIS

Real Estate Studies

Associations between household characteristics and subsidy applications for energy efficient retrofits in residential real estate

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ABSTRACT

Recently the Dutch government issued a second subsidy round to create a financial incentive for owner-occupiers to adopt energy efficient retrofits. This second round is a continuation of the by the government as successful labeled first round. Evidence in academic literature shows that the ability to adopt energy efficient retrofits and successfully apply for subsidies varies between different types of households. These types of households are distinguished by dwelling-, socio-economic, and socio-demographic household characteristics. The aim of this study is to explore associations between household characteristics of owner-occupiers and their perceptions regarding the possibilities to apply for subsidies for energy efficient retrofits in the Netherlands. This study focusses on assessing the perceptions of owner-occupiers who in their perception could not or did not know whether they could apply for subsidies. By means of a multinomial logistic regression model the associations between the household characteristics dwelling type, construction period, net income, education, and age and the perceived possibility to apply for subsidies are explored. The results show significant positive associations between certain dwelling types, recent dwelling construction periods, and older age groups and owner-occupiers that in their perception could not or did not know whether they could apply for subsidies. This study extents the current limited literature on household heterogeneity on subjects regarding energy efficient retrofit and subsidies in real estate research. In practice the results underline the importance for more attention to deliberate targeting of different types of owner-occupiers in real estate policy development to accelerate the energy transition.

Keywords: Household characteristics; energy efficient retrofits; subsidy; SEEH; residential real estate; multinomial logistic regression; energy transition

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LIST OF ABBREVIATIONS

AR	Algemene Rekenkamer – Court of Audit
BZK	Ministerie van binnenlandse zaken en koninkrijksrelaties – Ministry of Interior and Kingdom Relations
CBS	Centraal Bureau Statistiek – Statistics Netherlands
EER	Energy Efficient Retrofit
EPC	Energy Performance Certificate
IAK	Integraal Afwekingskader – Integral Assessment Framework
KCWJ	Kenniscentrum Wetgeving en Juridische zaken – Knowledge center for Legislation and Justice
Min. J&V	Ministerie van Justitie en Veiligheid – Ministry of Justice and Security
RVO	Rijksdienst voor Ondernemend Nederland – Netherlands Enterprise Agency
SEEH	Subsidie Energiebesparing Eigen Huis – Subsidy policy for EERs
SER	Sociaal Economische Raad – Economic and Social Council
VvE	Vereniging van Eigenaren – Owners Association
WoON	Woononderzoek Nederland – Housing research for the Netherlands

1. INTRODUCTION

Over the past decades, increasing attention has been given to the impact of climate change on our day-to-day environment. Especially global warming, as a result of CO_2 emissions across the globe, is an important issue that should be countered (UN, 2015). Lanting (2018) underlined the need for action arguing that if current policies will not lead to a decrease of CO_2 emissions the US economy will be shrinking with 10% by 2100. Comparable predictions similar to the US are foreseen for Europe as well. It is clear that economic growth will be impacted by global warming through heat waves and extreme droughts (Engels, 2018). The Paris Agreement – in which the first global targets were set regarding a limit of 1.5 degree Celsius temperature increase – is fuelling the demand for sustainable solutions (Streck, Keenlyside, Unger, 2016 p.3; UN, 2015).

Focusing on our built environment, the European Commission argued that 36% of the current CO_2 emissions within the European Union are produced by buildings. The majority of the older buildings are energy inefficient compared to the more recently built ones. This is an issue that should be addressed (EC, 2018). The Dutch government therefore formulated a target to reduce CO_2 emissions up to 2050 between 80% and 95% compared to 1990 (Ros & Schure, 2016). Over the past two decades the Dutch government has introduced different policies and new regulations in order to reduce the CO_2 emissions from existing dwellings. A recent policy is the "Subsidie Energiebesparing Eigen Huis" (SEEH); a subsidy to stimulate owner-occupier households to adopt energy efficient retrofits (EER), leading to energy efficient dwellings and reducing CO_2 emissions (Staatscourant, 2016). The SEEH focuses on EERs that increase the insolation of dwellings with a subsidy budget of €20,5 million. From August 2016 until April 2017 owner-occupiers had the possibility to apply for subsidies (Staatscourant, 2016; Staatscourant, 2017). This has been marked as the first round.

In August 2019 a second round SEEH was launched with a budget of €84 million euro. During the post-decision-making phase for the second round the first round was evaluated (BZK, 2018). However, the data-collection and results of this evaluation report are limited. Firstly it only focuses on the owner-occupiers who applied for the SEEH and secondly it is limited in its conclusions and interpretations (BZK, 2018). A comprehensive insight into the owner-occupiers that did not apply for the subsidies is missing. Therefore, the actual performance of the first round SEEH, based on the evaluation, is questionable since only a small part of the predetermined SEEH target group is included. Furthermore, it seems that the second round SEEH is based on incomplete evaluation report conclusions. Since the main purpose of the SEEH is to stimulate all owner-occupiers to adopt EERs it is relevant for society to examine the SEEH application process among different types of owner-occupier households - in particular households who did not apply. This examination leads to new insights for real estate policy makers to improve future SEEH policies and increase acknowledgement for the heterogeneity of households. In the long run, to reduce CO_2 emissions it is imperative to stimulate more household types to adopt EERs.

In residential real estate literature various authors focus on associations between household characteristics, energy efficiency and energy-saving related topics. This literature can basically be divided in three research fields. The first area focuses on explaining differences between the capitalization, by means of EPCs, of the EERs by the differences in users who adopted the measurements. The trustworthiness of the EPCs depends on user specific characteristics (Amecke, 2014; Murphy, 2014; Chegut, Eichholtz & Holtermans, 2016; Cassee, 2019). However, in-depth research on the underlying characteristics is missing. The second research field contains literature on the associations between the actual energy use of households and the adopted EERs. Sorrel, Dimitropoulos, & Sommerville (2009), Guerra-Santin & Itard (2012), and Gillingham & Palmer (2014) found evidence for a so-called 'rebound effect' in which households started to use more energy after adoption of EERs. Jarmo (2013), Aydin, Kok & Brounen (2017), and Brounen, Kok & Quigley (2013) explained these rebound effects through differences in dwelling, socio-economic, and socio-demographic characteristics among households. Besides these characteristics the authors further pointed out that the level of awareness towards climate change and energy-saving behavior is an important differentiator as well. However, this field of research revolves in particular around energy-saving behavior after EER adoption. The third and final research field focuses on determining the associations between household characteristics and energy efficiency and energy-saving related issues in residential real estate. Compared to the previous research fields, the amount of scientific literature in this third field is limited. Mills & Schleich (2012), who conducted cross-European research – excluding the Netherlands – showed that higher education, age, and household composition are associated with EER adoption. Michelsen & Madlener (2012) added evidence for different dwelling specific characteristics, higher income, and location. Trotta (2018) and Schleich (2019) further substantiated the influence of the mentioned household characteristics and further showed that the environmental awareness of households is positively associated with EER adoption as well. Worth noting is that research regarding associations between household characteristics and financial incentives to stimulate EER adoption barely exists. Sardiano & Genaudi (2013) showed, based on a questionnaire carried out before actual implementation of EERs, that subsidies could be a positive stimulus for households to adopt EERs. However, they argued that there is a difference between pre-action and post-action. Besides the lack of substantial literature on household characteristics and EER adoption, it is notable that the starting point for the majority of existing literature are households who adopt EERs. Almost no literature exists in which the households who did not adopt EERs are the starting point, which adds to the existing gap in literature addressed above.

The academic relevance of this study is firstly to expand the currently limited literature on associations of different household characteristics and the application for EER subsidies in the - almost never addressed - Dutch context. Secondly, to create new insights into the households who did not apply for EER subsidies or adopted EERs instead of the current academic focus on households who did apply. Finally, to find new evidence in the currently underexposed research field of household heterogeneity

in real estate research. This academic relevance, in combination with the limitations of the first round SEEH evaluation report, a recently launched second round SEEH, and increasing necessity for sustainable dwellings to meet climate change targets together form the relevance for this study.

The aim of this study is to evaluate the application process of the first round SEEH among owner-occupiers who in their perception could not apply or did not know whether they could apply for subsidies. This is done by exploring possible associations between contextual household characteristics and the application process for EER subsidies. This should lead to the identification of different influencing contextual household characteristics as explanations for the differences between EER subsidy adoption among owner-occupiers. Academically, the conclusions will add to the existing body of literature on the associations between the heterogeneity of households and EER subsidy adoption and – moreover – the influence of household characteristics in residential real estate. For societal purposes the conclusions should function as a body of advice for policy development. The main research question following this aim is:

"What is the association between contextual characteristics of owner-occupied households and the perceived possibilities to apply for subsidies for energy efficient retrofits in the Netherlands?"

In order to answer the main question two sub-questions have been defined. The first sub-question zooms in on determining the relevant household characteristics by discussing the scientific literature and the current SEEH policy structures. This results in a conceptual model and five hypotheses (chapter 2 and 3). The second sub-question focuses on determining the actual associations between the household characteristics and the application for EER subsidies. The associations are measured by applying a multinomial logistic regression to a sample (N=11,179) from the recent published WoON database 2018 (chapter 4). For four of the five included household characteristics significant results are observed (chapter 5), which for a majority show similarities to the assumptions in relevant scientific literature (chapter 6). This study highlights for further scientific research the influence of household heterogeneity during the application processes for subsidies, especially focusing on households that did not or cannot apply instead of household that did apply for subsidies. Finally for governmental real estate policy makers this study underlines the importance for more awareness to differences in household characteristics in order to stimulate all households to apply for subsidies and reduce CO_2 emissions (chapter 7).

2. DUTCH SEEH POLICY

This study focuses on an evaluation of the first round of SEEH policy. To get a better understanding of subsidies as a governmental policy tool it is necessary to explain subsidies and the purpose of SEEH.

This chapter will briefly explain the underlying idea behind subsidies, connect it to the SEEH policy, and explain the SEEH policy.

2.1 Subsidies in Dutch policy development context

The Dutch national government *"Rijksoverheid"* is responsible for policy development, enacting laws and regulation, execution of the policies, and monitoring the execution. An Integral Assessment Framework for Policy and Regulation "*Integraal Afwegingskader – IAK*" is used as guidance for policy development processes (Min. Veiligheid & Justitie, 2016). Breaking down this framework, three different phases can be defined. Firstly, the *problem analysis* in which the cause for action, involved stakeholders, problem, and the level of legitimacy for interference are defined. Secondly, the *appropriate choice of instruments for governmental interference* is described based on the problem and legitimacy. Examples of instruments are execution by the public authorities itself, regulations, excise duties, subsidies, and information provision. The final brings in *ex-ante and ex-post impact assessments*, in which monitoring and evaluations of policies and chosen instruments are executed (Min. Veiligheid & Justitie, 2016; SER, 2010). A key consideration during - particularly - the first two phases is the degree of public interest in order to determine the necessity for governmental interference. The Ministry of Justice and Security (2019) defines four different questions for determining the degree of interference. Table 1 presents these questions with a brief explanation:

Table 1: Steps to determine public interest and possible cause for governmental action
Source: Min. Justitie & Veiligheid (2019)

Question before action	Explanation
Is there a task for the government?	Assess whether interference is part of the main constitutional tasks of the national government. Issues regarding safety, rule of law, protecting traditional and fundamental social rights, equal treatment of citizens, and human rights.
Is redistribution of wealth necessary?	A skewed distribution of wealth among inhabitants.
Is there a reason for correcting behavior?	The negative impacts of goods on inhabitants. Example are anti-smoking campaigns.
Is there a disfunction or failure of the market?	If functioning of the market makes little or no contribution to societal prosperity, public interest may be at stake. Different types are possible: - External effects that cannot be corrected by the market; - Public and collective goods; - Information asymmetry in supply and demand; - Unfair competition; - Too high transaction costs.

After determining the public interest as basis for governmental interference it is important to develop a strategy with appropriate instruments for execution - the second phase of the IAK. In the case of the SEEH policy the government chose for a subsidy (Staatscourant, 2016). Subsidies are qualified by de government as an indirect financial instrument for economic regulation. By creating financial incentives, target groups are steered towards desirable behavior and actions in line with policy goals without an active executive role by the government. In practice a subsidy is a financial compensation for a certain

expenditure (KCWJ, 2012). According to the KCWJ (2012), the advantage of subsidies is the positive and stimulating way to influence people's behavior. Furthermore, when formulating clear application conditions it is a proper steering instrument. However, KCWJ (2012) also mentions several disadvantages of subsidies. Exercising control after issuing is limited and as a unilateral financial incentive it leads to limited attention for other non-financial instruments. Furthermore it is difficult to evaluate and monitor the success of subsidies. Boomhower & Davis (2014) explicitly add to the difficulty in the evaluation of subsidies that it is questionable whether a subsidy in reality led to a certain action or if the action had been executed as well if the subsidy was not issued. Although the monitoring and evaluation process is the official last phase of the IAK, in 2011 the Dutch Court of Audit (Algemene Rekenkamer – AR) raised concerns. According to the AR by 2011 only 12% of the issued subsidies between 2005 and 2009 had been evaluated (Israël, van den Dongen, Gorrée, van der Kraan & de Witte, 2012). This underlines the advantages and disadvantages of subsidies as instruments to stimulate target groups.

2.2 Subsidies for EERs and the SEEH

Focusing specifically on the subject of governmental interference to stimulate EER adoption in residential real estate, it seems that literature and economic reports have a predominant preference for governmental interference. Allcott & Greenstone (2012) argued that government interference is legit because the discussion regarding EERs is not only about single profits but is part of a lager societally relevant debate. Firstly, they mentioned that an acceleration of EER adoption is necessary to reduce the use of fossil fuels which have negative externalities on human health and climate change. Secondly, the existence of imperfect information leads to hesitation in private investments regarding energy efficiency. The external effects and information asymmetry mentioned by Allcott & Greenston (2012) underline a possible failure of the market, as described by the Min. Veiligheid & Justitie (2019) and therefore the necessity to interfere. Furthermore, in 2009 the consultancy group McKinsey & Company underlined the economic potential in the US market from the increasing energy efficiency market. However, this potential should be unlocked by strategic governmental interference focusing on stimulation and reducing asymmetric information (McKinsey & Company, 2009). Similar conclusions were made years later by Deloitte (2016) in their report on energy efficiency in the European market.

On the national Dutch level, the government decided in august 2016 to implement the "*Subsidie Energiebesparing Eigen Huis (SEEH)".* This first round subsidy for EERs for owner-occupied dwellings was the result of a decision in December 2015 to accelerate the energy saving/efficiency arrangements made in the Energy Agreement for Sustainable Growth in 2013 (Staatscourant, 2016). The purpose of the subsidy was to stimulate energy efficiency in existing owner-occupied dwellings in the private sector and in owner associations "Vereniging van Eigenaren (VvE)" (Staatscourant, 2016). Noticeable is that the government perceived that the targets in the Energy Agreement 2013 should be accelerated, and therefore chose a stimulation policy. Through a stakeholder interaction process with

among others the *"Vereninging van Nederlandse Gemeenten (VNG)",* the construction sector, and interest groups of homeowners the structure of this subsidy was developed. Table 2 shows a summary of the first round SEEH policy. The duration of the first round SEEH policy was from September 2016 until April 2017 when the limit of the subsidy was reached (Staatscourant, 2017). From September 2019 again a SEEH was implemented, therefore, in this study the first period 2016-2017 is marked as the first round SEEH policy.

Table 2: Summary of the main components of the first round SEEH policy.
Source: Staatscourant (2016)

Main components	Explanation
Target group	Owner-occupiers: Homeowner who will use or is already using the property as main residence.
Main purpose	The purpose of the subsidy is to reduce fossil fuel use through stimulating adoption of EERs.
Subsidy sealing	€20.5 million euro.
Covered measurements	The EER by the subsidy are cavity wall insulation, façade insulation, roof insulation, floor- or bottom- insulation, and high efficiency glass .
Types of covered houses	The following types of houses are covered by the subsidy: detached houses, semi-detached houses, terraced houses, floor units, and apartment units.
Conditions	Different requirements and conditions to apply for a subsidy are: - Two or more measurements have to be taken. The underlying reason to this decision is the change that applications would only adopt a single measurement, which they maybe would have done without the subsidy as well. The Staatscourant (2016) explains this as a correction for an additional effect; - Per above mentioned housing type a minimum of square meters is given that has to be redeveloped; - A at the Chamber of Commerce registered company has to execute the activities; - A customized advice report or an energy performance guarantee needs to be included in the application.

In June 2018 the evaluation of the first round SEEH policy was published. A total of 19,313 owner-occupiers applied for the subsidy, for a total amount of 52,781 single EERs. Based on seventeen questions answered by 3,535 respondents, who applied for a subsidy, the evaluations quantifies different factors. The evaluation shows that 67% of the respondents mentioned that the subsidy was the their final stimulation for execution of EFMs. Furthermore, it gives an insight into dispersion of housing types, type of EERs, locations and main reasons. Finally, it briefly touches on background characteristics of the owner-occupiers. These are income separated in three classes, age separated in seven classes and education in six different levels (RVO, 2018).

However, the evaluation report is too limited in terms of data gathering and interpretation of the results to define sound conclusions. Firstly, the report only focuses on a selective target group of owner-occupiers that applied for the SEEH subsidy. It does not focus on households who nevertheless are an initial target group of the SEEH but did not apply for it. Secondly, the evaluation only gives a limited insight into the different background characteristics of owner-occupiers who adopted it. Finally, the evaluation only presents descriptive statistics of the data which does not give an insight into relations

between characteristics of households and the performance of the SEEH policy. Recently, a second round SEEH policy was implemented and started in September of 2019. The decisions-making regarding this second round of SEEH policy, in which the total subsidy budget increased with a factor 4,5, is based mainly on the incomplete evaluation report of the first round (Staatscourant, 2019).

3. LITERATURE & HYPOTHESES

3.1 Literature review

The influence of contextual household characteristics and EERs in owner-occupied residential real estate is recurring in various research topics. Studies by Brounen & Kok (2011), Fuerst, McAllister, Nanda & Wyatt (2015), Chegut et al. (2016), and Jensen et al. (2016) concentrate on the capitalization of EERs, through Energy Performance Certificates (EPC), and touch on the possible influences of heterogeneous households on the effectiveness of EPCs. Amecke (2014), Murphy (2014) and Cassee (2019) substantiate these assumptions by finding evidence for associations between the trustworthiness and recognition of EPCs and contextual characteristics – in the end affecting the price premium levels. Looking at studies regarding the actual energy use and adopted EERs, Majcen, Itard & Visscher (2013) present positive associations between adopted EERs, leading to a higher EPC, and increasing energy consumption by households. Sorrel et al. (2009), Guerra-Santin & Itard (2012), Gillingham & Palmer (2014), and Aydin et al. (2017) find similar results and interpret these results through a 'rebound effect' among homeowners that implemented EERs. They conclude that the actual implications of EERs cannot be estimated in standardized labels (EPCs) and models due to differences between households. Aydin et al. (2017) and Jarmo (2013) explicitly focus on determining these effects of the contextual factors. Jarmo's (2013) study shows positive associations between building characteristics (construction period, square meters, number of rooms) and household characteristics (age, income, household size) and the actual energy use of households. These results are in line with Aydin et al. (2017) who are mentioning the importance of including the heterogeneity of households. Focusing on the aspect of awareness among households on their current energy costs and possible investments in EERs, Brounen et al. (2013) show that associations exist between characteristics as income and age and certain levels of energy costs awareness. Given the scope of this study, it is not relevant to further zoom in on the scientific literature on capitalization of EERs, actual energy use in relation to EERs and awareness of energy costs and possible investments of households. Nevertheless it is important to make mention of it since the authors underscore the need for further research on contextual household characteristics in their various EER research topics.

Several studies have been conducted of the last decade looking more closely at the influence of household characteristics on EER adoption and the application for related subsidies. In a substantial cross-country study in Germany, France, Italy, United Kingdom, and Spain, Nicolini & Tavioni (2017) evaluate the performance of financial incentives – through feed-in tariffs – for stimulating renewable

electricity production in the period 2000–2010. Results show associations between subsidies and energy production and, furthermore, an increase in installed capacity. Although the results show the impact of subsidies, Nicolini & Tavioni (2017) combined subsidies from macro scales – large offshore wind energy projects – to micro scales – solar panels on own dwelling, making it impossible to break down their conclusions to individual household levels and determine household characteristics.

Zooming in on the micro level, Sardiano & Genaudi (2013) focus on determining the influencing factors for the willingness of homeowners to adopt EERs in Greece. The results from a binary probit regression model indicate that middle-aged and highly educated households are more willing to adopt EERs. The results show further associations between higher income groups and willingness to adopt EERs. Marital status and gender did not show significant results. Finally, Sardiano & Genaudi (2013) conclude that households prefer tax benefits over subsidies. The basis for the conclusions are a sample of answers regarding intentions of homeowners to adopt EERs, limiting its robustness because of a possible gap between intentions and actual actions. Mills & Schleich (2012) conduct a similar study in which they focus on a sample of approx. 5,000 households across ten European countries – the Netherlands not included. They examine possible associations regarding attitudes towards energy saving and already adopted EERs in relation to various household characteristics. Through an OLS regression Mills & Schleich (2012) find positive associations between young- and middle-aged households and adoption of EERs compared to older households. Regarding household composition their results show further significant associations between households with children compared to household without children. For the characteristic education the results are significant as well, indicating an association between higher education and more EER adoption. Finally, Mills & Schleich (2012) present evidence for differences between European countries. West-European countries are more likely to adopt EERs in comparison with East-European countries. Limiting Mills & Schleich's (2012) study is the issue of taking into account financial incentives, as it solely focuses on the influence of characteristics. Moreover it remains difficult to compare European countries since policies and perceptions of homeowners are different per country. Years later, Schleich (2019) again conducts a cross-country study across eight European countries – the Netherlands not included – in which he examines the adoption of low-, middle-, and high-cost EERs with a sample of approx. 15,000 households. Schleich (2019) focuses on assessing the influence of income, age of respondent, building age, type of building and environmental awareness through a logistic regression model. The cross-country nature of Schleich's (2019) study results in different findings per country. In general, only the lowest of four income groups shows significant results compared to the highest income group. Age is in the majority of countries significant and higher age groups show positive associations with higher adoption rates. Type of dwelling is significant for all countries. Building age shows significant results as well, suggesting that recently built buildings have less EER adoption. Finally, higher environmental awareness shows a positive association with a higher EER adoption rate (Schleich, 2019). Limitations of this study are again the difficulties in comparing

countries. Moreover this study and the study by Mills & Schleich (2012) are not taking into account that groups with lower incomes obtain – in some of the countries – compensations for investments in EERs.

Comparable to the study mentioned above, Trotta (2018) focuses on determining the strongest socio-demographic-, dwelling- characteristics and pro-environmental attitude characteristics on EER adoption among British households. Trotta (2018) assesses the characteristics age, marital status, gender, education, income of households, dwelling type and environmental awareness in relation to EERs. Age results show a significant positive association between EER investments and higher age categories in comparison with lower ages. Being married shows a significant positive association with EER adoption. The same applies for the character income which is significant for every income group with lowest income as reference category. As income rises the positive association grows stronger. The characteristic education is not significant – this time – and dwelling type is only partial significant. Finally, the pro-environmental attitude does not show any significant results (Trotta, 2018). Michelsen & Madlener (2012) zero in – within a German context - on a particular set of EERs in terms of residential heating systems and the driving forces to adopt which type of system. The authors focus on defining the influences of socio-demographic (income, age, education, gender), home (size, construction period, type, renovations, retrofits), spatial (Rural, east south), and heating specific characteristics. The authors apply a multinomial logistic regression model. The results show that the socio-demographic category income, age, and education have significant effects. Higher income and higher education have a higher association with the more environmentally friendly heating systems. Age shows, although it is only a small measure, that respondents that are older are favoring traditional heating systems. Furthermore in the category home the characteristics size and construction period show significant associations with heating systems (Michelsen & Madlener, 2012).

The articles discussed here mainly focus on the influence of household characteristics in different European countries but exclude the Netherlands. Looking at recent studies on EERs and household characteristics in a Dutch context, publications are limited to not existing. Although the study by Aydin et al. (2017) focuses on determining the 'rebound effect' in energy saving, and therefore differs from the research aim of this study, the authors elaborate on the importance of taking household heterogeneity into account. Aydin et al. (2017) find particular evidence for associations between household income and wealth and the level of actual energy saving after EER installation. Furthermore, they control in their statistical models for dwelling type and size, construction period, household composition, and employment. Given their conclusions, Aydin et al. (2017) are explicitly underlying the importance for research into the household heterogeneity in studies on sustainability in residential real estate.

Table 3 presents an overview of the main household characteristics that are mentioned in the literature above. Based on the nature of the variable, the characteristics encourage a categorization in

four groups; dwelling, socio-economic, and socio-demographic characteristics, and finally environmental awareness.

Table 3: Frequently used household characteristics in literature per author
Source: Own work.

Categorization in conceptual model	Characteristics	Reported by
Dwelling Characteristics	Dwelling type*	Schleich (2019); Trotta (2018); Brounen & Kok (2012); Chegut et al. (2014); Aydin et al. (2017)
	Construction period*	Schleich (2019); Michelsen & Madlener (2012); Aydin et al. (2017)
	Dwelling surface**	Michelsen & Madlener (2012); Aydin et al. (2017)
Socio-economic characteristics	Income*	Sardiano & Genaudi (2013); Schleich (2019); Trotta (2018); Michelsen & Madlener (2014); Aydin et al. (2017)
	Education*	Sardiano & Genaudi (2013); Mills & Schleich (2012); Trotta (2018); Michelsen & Madlener (2014)
Socio-demographic characteristics	Age*	Sardiano & Genaudi (2013); Mills & Schleich (2012); Schleich (2019); Trotta (2018); Michelsen & Madlener (2012)
	Household composition**	Mills & Schleich (2012)
	Marital status	Sardiano & Genaudi (2013); Trotta (2018)
	Gender	Sardiano & Genaudi (2013); Trotta (2018); Michelsen & Madlener (2012)
Environmental awareness	Willingness to invest**	Mills & Schleich (2012); Aydin et al. (2017); Trotta (2018); Schleich (2019)

Note: *included as predictor **included as control variable

3.2 Towards the conceptual model

Based on the literature discussed above on different contextual household characteristics the conceptual model for this study is drafted, which is shown in Figure 1 below. Recurring dwelling characteristics are the type of dwelling and construction period. Schleich (2019), Trotta (2018), and Michelsen & Madlener (2012) apply the type of dwelling in their studies on contextual influences on EERs. Brounen & Kok (2012) and Chegut et al. (2014) apply dwelling type as well in their studies on capitalizations of EERs. Only Schleich (2019) includes the characteristic as a binary variable (detached and others) and the other authors in four categories (flat/apartment, terraced, semi-detached, detached). The results per study show differences in terms of significance level per category and consistency in associations. Generalizations on the basis of the literature review are therefore difficult. Nevertheless, the above mentioned authors emphasize the relevance to include this variable in study on the influence of household characteristics. Schleich (2019) and Michelsen & Madlener (2012) apply the characteristic construction period in relation to EERs. Schleich (2019) shows that households living in dwellings more recently constructed are less focusing on EER adoption. An explanation is that these households assume that because their dwelling is recently built it is energy efficient already. Michelsen & Madlener (2012) present similar evidence for significant associations between recent construction periods and more environmental friendly heating types. They elaborate that it seems logical that a recent construction

period is associated to more energy friendly heating types, since heating systems are evolving. The authors use this variable therefore as a proxy for the technical state of a building. Both dwelling type and construction period are part of this study's conceptual model (Figure 1). Further control variables such as dwelling surface are added as control variables.

In literature frequently recurring socio-economic household characteristics are income and education. Worth noting is that the level and number of associations differ per study. Schleich (2019) presents evidence that in some countries only the lowest of his four income groups shows an association with the adoption of EERs, indicating that low income could lead to less adoption. Sardiano & Genaudi (2013) show a broader base of evidence in which they conclude that as income rises the willingness to adopt rises as well. However, the basis for this study are perceptions towards EERs and not on actual adoption numbers. Trotta (2018) presents results that his three of four highest income groups are significant and identifies income as an influencing factor for EER adoption. Michelsen & Madlener (2012) show associations between higher income and more environmental friendly heating types. Income seems to be an important characteristic for EER adoption yet shows significantly different results across literature. Finally, Aydin et al. (2017) identify income as an important household characteristic to underline the need for further research. The characteristic education is in its results less stable in comparison with income. Mills & Schleich (2012) found evidence for an association between higher income and a higher adoption of EERs. Results in line with Sardiano & Genaudi (2013) who indicate that education is associated, however only the category highly educated is actually associated. Michelsen & Madlener (2012) further substantiate these findings by showing positive associations between the higher educated categories and more environmental friendly heating types. The results from Trotta (2018) are also noteworthy as they could not identify education as a household characteristic for EER adoption due to lacking significant results. Given the broad base of research on education and income both variables are part of this study's conceptual model (Figure 1).

The most frequently recurring socio-demographic household characteristic in literature is age. Further characteristics are household composition, marital status, and gender. Sardiano & Genaudi (2012) conclude that middle-aged categories are more likely to adopt EERs in comparison with the youngest category. Mills & Schleich (2012) are expanding and substantiating the previous findings by showing associations between middle- and young-age categories and EER adoption. Michelsen & Madlener (2014) are arguing that older age groups favor traditional heating systems and younger age groups favor the more environmental friendly systems. However, their results are only significant at a high significance level. Contrasting the authors above, Trotta (2018) and Schleich (2019) present evidence for associations between higher age categories in comparison with the lower age categories and EER adoption. These two authors explain their findings by referring among others to rising awareness in combination of increasing means to actually act. The less frequently recurring characteristics of household composition, marital status, and gender show contradictory results across the above literature. The status of being married is significantly associated with EER adoption in Trotta's

(2018) study yet not significant in Sardiano & Genaudi's (2013) study. Gender is not significant in either Sardiano & Genaudi (2013), Trotta (2018), or Michelsen & Madlener (2012) studies. Finally, Mills & Schleich (2012) present evidence for a positive association between households with children and a higher EER adoption. Since the association between age and adoption of EERs is frequently recurring in literature age is part of this study's conceptual model (Figure 1). Household composition is included as one of the control variables and marital status is not included.

The fourth category of environmental awareness focuses on the perception of households of environmentally friendly dwellings and the need to adopt EERs. Mills & Schleich (2012), Trotta (2018) and Schleich (2019) assume that an association exists between knowledge, awareness, and attitude on environmental issues on the one hand, and energy responsible behavior leading to EER adoption on the other. Trotta (2018) did not find any significant associations between environmental awareness and adoption of EERs. On the contrary Schleich (2018) did find a positive association between households with a higher environmental awareness and higher EER adoption. The argument Mills & Schleich (2012) bring to the table places these results more into perspective. They argue that the environmental awareness also depends on income and education. They conclude that households with a lower income and low level of education are primarily focusing on decreasing the costs when adopting EERs. Vice versa, the high income and high education households have a higher motivation for EERs solely because of environmental reasons. The results show that environmental awareness is an important factor in EER adoption. However, the actual influence is still subject of debate. Therefore this category is added as control variable (Figure 1).

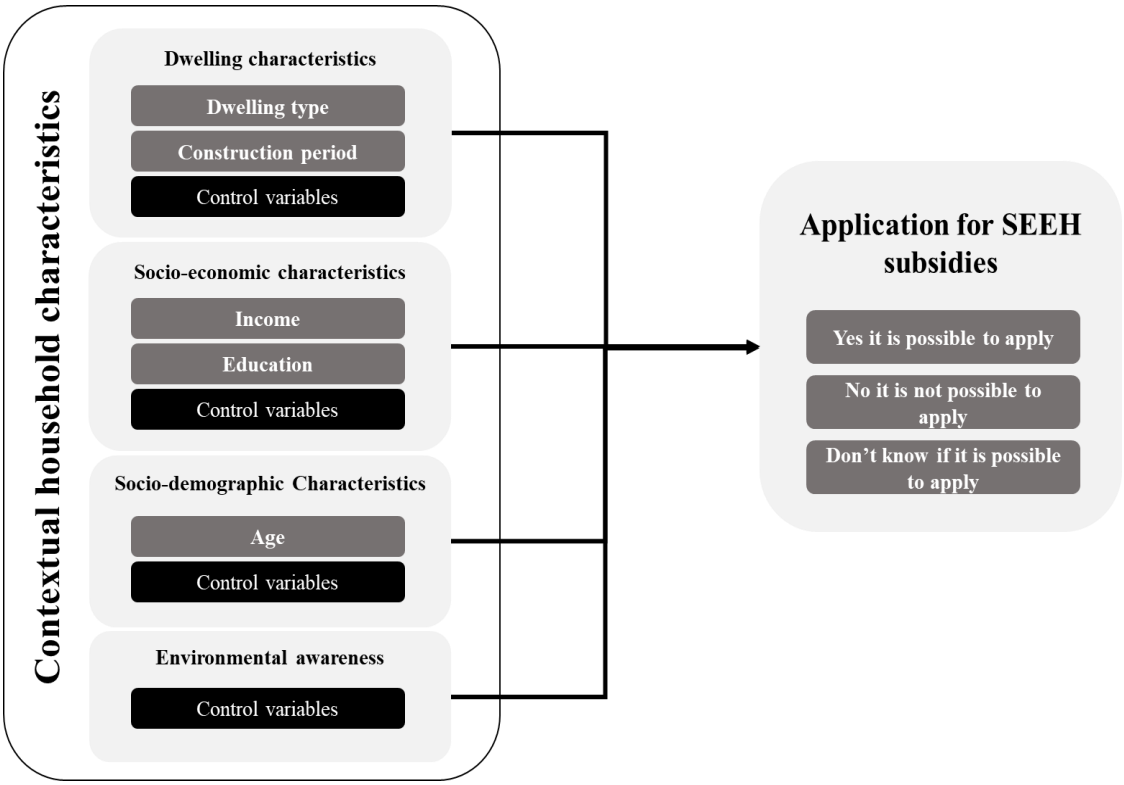

Figure 1: Conceptual model.
Source: Own work

The four categories discussed above as well as the relevant predictor variables – *dwelling type, construction period, net income, education* and *age* – are visualized on the left side of the conceptual model (Figure 1). Furthermore, every category includes control variables (Appendix 2.2). The aim of this study is to measure the possible association between the predictors, controlled by control variables (left side), and the application for SEEH subsidies (right side). As shown, the nominal dependent variable contains three categories.

3.3 Hypotheses

The conceptual model above assumes possible associations between the five household characteristics (left side) and the application process for SEEH subsidies (right side). Since the dependent variable for this study is a nominal variable with three categories a multinomial logistic regression model is applied. Important to mention is that the category 'yes it is possible to apply' will function in all regression models as reference category since the focus of this study are owner-occupiers that in their perception could not or did not know that it was possible to apply for subsidies. The assumptions regarding the assumed associations lead to the formulation of the following five hypotheses:

Dwelling characteristics

H1: It is expected to find a positive association between higher degree of connectedness of a dwelling to neighboring dwellings (flat/apartment, terraced, semi-detached ref: detached) and the category no possibility to apply and don't know if it is possible to apply for EER subsidies.

H2: It is expected to find a positive association between recent construction period of dwellings and the category no possibility to apply and don't know if it is possible to apply for EER subsidies.

Socio-economic characteristics

H3: It is expected to find a positive association between lower degree of education and the category don't know if it is possible to apply for EER subsidies.

H4: It is expected to find a negative association between net income and the category no and don't know if it is possible to apply for EER subsidies.

Socio-demographic characteristics

H5: It is expected to find a positive association between a higher age and the category no possibility to apply for EER subsidies.

4. DATA & METHODOLOGY

4.1 Study design, population and data collection

The aim of this study is to evaluate the first round SEEH policy for owner-occupied dwellings by determining the influences of different contextual household characteristics among homeowners. A quantitative research design is used to explore possible associations between different contextual

household characteristics and the applications for the SEEH policy. The data source for this quantitative study design is the Dutch WoON Survey 2018. The Dutch WoON-survey is a three-year survey executed by the Ministry of Internal Affairs and Kingdom Relations. The survey creates an insight in the residential situation, particular choices, preferences, and opinions of Dutch households within the residential market. Due to the WoON-surveys comprehensive and extensive nature it is the basis for Dutch policy processes, knowledge development regarding living and building, a source to answer parliament questions, and a source for development models on housing demands. The database is perceived as a reliable source of information for policy makers and research since it is a trustworthy source of information. The WoON-database 2018 is a publicly accessible source which was attained from the webpage 'https://www.woononderzoek.nl/', after approval of the responsible governmental authority (Woononderzoek.nl, April 2019). However, it is a disadvantage that WoON is not repeated among the same population every three years and is therefore not a reliable source for longitudinal study designs. Analyses on trends across time – which in the light of measuring the energy transition progress would be interesting topics – are possible only to a limited degree. The research design of this study has a cross-sectional approach and will only include the results of the WoON 2018. The WoON results and database were published in April 2019 and contain a total of 67,523 observations among different households in the Netherlands. This total amount of observations contains owner-occupiers, tenant-occupiers and blank observations. Given the aim of this study, owner-occupiers were selected from the total database and tenant-occupiers and blanks were dropped. For the category marked as blanked it is not clear whether it concerned owner- or tenant- occupiers. This study contains a sample of 37,899 observations. Table 4 shows the distribution among these categories. Although this data selection is reducing the number of observations, it is a necessary step given the aim of the study.

Table 4: Distribution of owner- and tenant- occupiers and blank observations.
Source: WoON (2018)

	Number observations	**Percentage**
Owner-occupier	37,898	56.1%
Tenant-occupier	21,454	31.8%
Blanks	8,171	12.1%
Total	67,523	100%

4.2 Variables and operationalization

The sample for this study contains a total of 934 different variables focusing on a wide range of topicalities which are relevant to households. Through the combination of the literature, discussed in the second chapter, the research aim and the possibilities of the WoON-database the relevant variables are selected.

Dependent variable

The selected dependent variable is qualified as a nominal variable with three different groups (Table 5). The groups are the three answer possibilities to a single question from the WoON-Survey on: '*whether it was in the perception of the owner-occupier possible to apply for subsidies in the case of EER investments'.* Important to mention is that this question is a follow-up question to the question: '*if home-owners did implement energy efficient retrofits in their dwellings'*. If they did not, the respondents were excluded from the question on whether it was possible to apply for EER subsidies. Due to this selection in in the WoON-questioner the variable 'possibility to apply for EER subsidies' contains 19,301 observations.

Table 5: Description of the dependent variable: perceived possibility to apply for EERs subsidy.
Source: WoON (2018)

Groups	Variable type	Number of observations	Description
1. Yes, it is possible; 2. No, it is not possible; 3. Don't know if it possible to apply.	Nominal Variable	19,301	The perceived possibility of owner-occupiers to apply for EER subsidies expressed in three answer possibilities in the WoON survey.

Further operationalization of the dependent variable leads to further reduction of the sample size. The question in the WoON-Survey on the subsidy, used as dependent variable, is broadly formulated in relation to a large number of different EERs. The survey lists possibilities from EERs on glass insulation, insulation of roof, walls and floors to solar panels, energy efficient heating, and other energy efficient and saving measurements. Therefore, there is a likelihood that in the case of an application for a subsidy there could not be a direct connection to EERs on insulation. This particular connection is relevant for this study given the focus on an evaluation of the Dutch SEEH policy. In the WoON-Survey two questions are focusing on whether insulation EER are executed. These are translated into two different binary variables (Yes/No) in the database. By combining these two binary variables with the previous selection of 19.301 observations a second selection is executed in order to drop further irrelevant observations. In the event that a respondent responded the survey with the answer 'no' to both questions on insulation materials, the observation is dropped. Finally, 105 observations are dropped due to data cleansing in the predictor variables. Important to underline is that this selection led to a sample of owner-occupiers who in principle could all apply for Dutch EER subsidies. Table 6 is a summary of the outcome of this data cleansing process. Appendix 1 shows a visualization of the operationalization of the dependent variable.

Table 6: Overview after data selection for dependent variable.
Source: WoON (2018) – Own work.

	Relevant observations	Dropped observations
Yes	502	111
No	5,045	4,644
Don't know	5,632	3,365

Total	11,179	8,100

Looking at literature – similar to this study in terms of methodology and content – Trotta (2018) had a sample size of 1,290, Schleich (2019) in his country comparison had fluctuating observations per country in a range from 595 to 1,100, and Mills & Schleich (2012) had a sample size of 4,896. Given this literature the final sample size of this study (N = 11,179) is sufficient for doing research on this particular topic. In total 19,313 owner-occupiers applied in the first round for SEEH (RVO, 2018). The sample in this study contains 2.6% of the total population that applied for SEEH. However this study focuses on owner-occupiers that in their perception could not or did not know whether it was possible to apply for subsidies but did adopt EERs without subsidies. Currently no central register exists to keep track of all adopted EERs in the Netherlands. This makes it difficult to determine the relative sample size of owner-occupiers who in their perception could not or did not know whether it was possible to adopt EER subsidies pertaining to the total population.

Independent variables

Given the aim of this study, the literature led to a categorization of the four categories dwelling, socio-economic, socio-demographic characteristics, and environmental awareness. The categories entail different predictors. This study included the five most relevant predictors according to literature, as discussed in the previous chapter. Table 7 presents summary statistics on the five included predictors.

The included categorial variable *dwelling type* contains five different answer categories on the specific type of a dwelling. During operationalization the variable *dwelling type* was transformed from eight to five categories because of three categories with an insubstantial number of observations. The category 'other types' contains different types of dwellings that are underrepresented in the sample (e.g. farmhouse, storehouse). The variable *construction period* contains six categories with different time-periods regarding the construction period of a building of the respondent. The variable was operationalized by combining three categories into one, due to limited observation.

The socio-economic group contains the predictors *net income* and *education.* The variable *education* contains four different categories on the education level of the respondent. The first category contains lower educated respondents, which are the Dutch levels of *"Basisonderwijs, Vmbo, Havo-, Vwo-onderbouw, Mbo 1".* The second category are the middle-educated respondents, containing the levels *"Havo, Vwo and MBO 2, 3 and 4".* The third category are higher educated respondents, containing "*Hbo, Wo-Bachelor, Wo-master and PhD".* The fourth and final category are unknowns. The continuous variable *net income* (Table 8) is the net income per household. It is assumed that the actual net income has more impact on the budget of households and therefore gives a more realistic picture. The predictor *Net income* was transferred to a natural logarithm to correct for outliers and to control for collinearity.

The socio-demographic category includes the predictor *age*. The age of the respondents are operationalized in five categories due to limited observations.

Table 7: Summary statistics predictors
Source: Own work

Variables	Variable type	N	Mean ***Shares***	Std. Dev	Min	Max
Dwelling type	Categorial	11,179	2.65	1.01	1	5
- *Flat/Apartment*			*0.09*			
- *Terraced*			*0.46*			
- *Semi-detached*			*0.20*			
- *Detached*			*0.22*			
- *Other types*			*0.3*			
Construction period	Categorial	11,179	3.16	1.70	1	6
- *< 1945*			*0.28*			
- *1945 – 1959*			*0.10*			
- *1960 – 1969*			*0.15*			
- *1970 – 1979*			*0.23*			
- *1980 – 1989*			*0.13*			
- *> 1990*			*0.10*			
Education	Categorial	11,179	2.16	0.84	1	4
- *Low*			*0.27*			
- *Middle*			*0.33*			
- *High*			*0.38*			
- *Unknown*			*0.02*			
Net income	Continuous	11,179	€51,528.99	€30,353.53	€0	€959,960.00
Age	Categorial	11,179	3.33	1.38	1	5
- *< 34 year*			*0.13*			
- *35 – 44 year*			*0.17*			
- *45 – 54 year*			*0.21*			
- *55 – 64 year*			*0.21*			
- *> 65 year*			*0.27*			

Note: The table above shows for the categorial variables the distribution per variable category as shares from the total number of observations.

A detailed overview on the considerations for the operationalization of the independent variables is added in Appendix 2.1 on data management and cross tabulations for the categorial predictors in Appendix 3.

Control variables

Control variables are added in this study to control for other effects outside of the experiment which could influence the results. The control variables in this study are other variables within the three categories dwelling-, socio-economic-, and socio-demographic- characteristics and a fourth category environmental awareness among households. For every category relevant variables are derived from theory concerning the influence of contextual factors on residential real estate related studies. Appendix 2 presents a detailed overview on the data management of the control variables. The table in the Appendix shows the different chosen variables, the categorization per category and, if necessary, transformations to operationalize the variable. Finally, it shows a description of each variable concerning its groups, categories and content.

4.3 Methodology

A multinomial logistic regression model is performed to explore the possible associations between contextual household characteristics and the perceived possibility to apply for subsidies for EER adoption among owner-occupiers in the Netherlands. In scientific literature on the influence of contextual characteristics and the adoption and performance of EERs, logistic regression models are frequently used instruments for analysis (Michelsen & Madlener, 2012; Sardianou & Genoudi, 2013; Trotta, 2018; Schleich, 2019). Logistic regression models are alternative regression methods for binary, ordinal, and categorical dependent variables. The models are regressing for the probability of binary and categorical outcomes. These probabilities are based on single or multiple continuous, discrete, and binary predictor variables. Since logistic models are non-linear models, estimations are based on the maximum likelihood (DeMaris, 1995; Starkweather & Moske, 2011; Moore, McCabe, & Graig, 2014). Logistic regression models estimate the odd-ratios in coefficients. These odd-ratios determine the probability that the dependent variable will be 0 or 1. Since coefficients do not show this effect odd ratios must be interpreted differently. Through the calculations of odd-ratios it is possible to measure an association between the probability that the depended variable will change if the predictor changes. If the odd-ratio is smaller than 1, the probability is that Y=1 will decrease, indicating a negative association. Vice versa, in the case that the odd ratio is larger than 1 the probability for Y=1 will increase, indicating a positive association. In a situation in which the odd ratio is equal to 1, no association exists (DeMaris, 1995).

The nominal dependent variable in this study exists of three categories, therefore, the use of multinomial logistic regression is the appropriate option. In order to evaluate the probability that outcomes fall into certain categories the multinomial logistic regression models uses, similar as the binary logistic regression models, the maximum likelihood estimations (Long, 2012). A frequently used form of the multinomial logistic regression model is a set of multiple independent binary regressions involving comparisons of every category to a reference category (Long & Freese, 2004; Long, 2012; Starkweather & Moske, 2011). The statistical model in this study evolves step by step from univariable-, multivariable- to adjusted multivariable models. Figure 2 in the following chapter 5 shows a visualization of this model development. Moreover, since the focus of this study is to determine the associations between five predictors and the dependent variable the statistical model is adjusted five times in order to explore every included predictor. The statistical equations for the five final adjusted multivariable models – including all predictors and control variables – are the following:

$$ln\left(\frac{P(Y=no)}{P(Y=Yes)}\right) = \alpha + \beta 1[\mathrm{EP}] + \beta 2[\mathrm{OP}] + \beta 3[\mathrm{CONTROLS}] + e \quad (1)$$

$$ln\left(\frac{P(Y=Don't\ know)}{P(Y=Yes)}\right) = \alpha + \beta 1[\mathrm{EP}] + \beta 2[\mathrm{OP}] + \beta 3[\mathrm{CONTROLS}] + e \quad (2)$$

In which $P(Y = no)$ and $P(Y = don't\ know)$ are the two categories that are compared to the reference category $P(Y = yes)$. α the constant, [EP] the explored predictor included in the univariable model, [OP] the other four predictors included in the multivariable model and [CONTROLS] the control variables included in the adjusted multivariable models. The data processing – execution of the regressions – and data analysis is carried out in STATA 16.0. The results are presented in chapter four by presenting adjusted odds ratios (aORs), standard errors (SE), and the significance levels. Key assumption for performing multinomial logistic regression is the assumption of Independence of Irrelevant Alternatives (IIA). IIA assumes that observations are independent from irrelevant alternatives. This applies that the categories in the dependent variable should be mutually exclusive and exhaustive (DeMaris, 1995; Cheng & Long, 2007; Starkweather & Moske, 2011). However, Cheng & Long (2007) are elaborating that testing for IIA with the frequently recurring 'Hausman McFadden' and 'Small-Hsiao' is complex and shows inconsistent results. Given these issues Cheng & Long (2007) are referring to McFadden (1974) who indicated, given the IIA assumption, that multinomial logistic models should only be applied when: ´Outcome categories can plausibly be assumed to distinct and weighed independent*'* (McFadden, 1974; p.113). The dependent variable '*possibility to apply for subsidies'* exists of three independent and exhaustive categories, therefore it is assumed that the IIA assumption in this study holds. Regarding the issue of collinearity, a VIF analysis is performed (Appendix 5) which does not show signs of collinearity between the predictors and dependent variable.

5. RESULTS

This chapter presents an analysis of the results from the performed multinomial logistic regression to test the hypotheses and include contextual characteristics outside of the research model used. The multinomial regression is performed for the categories dwelling characteristics, socio-economic characteristics - both containing two predictions -, and socio-demographic characteristics, containing one predictor characteristic. The ORs are calculated in a step by step way shown in Figure 2.

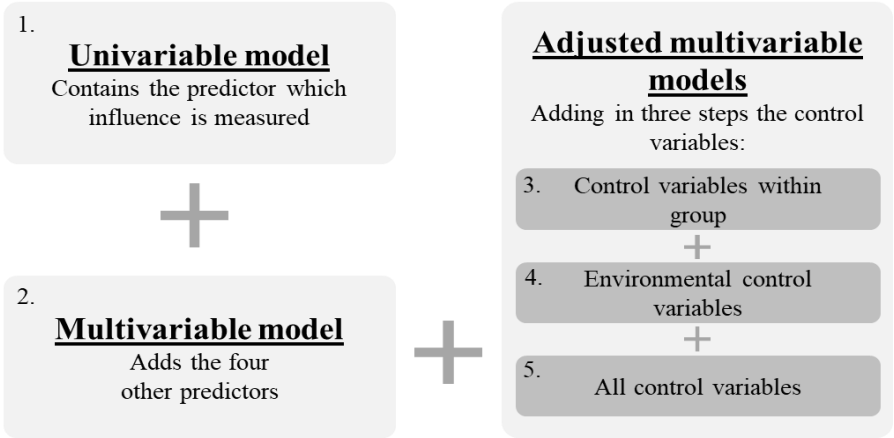

Figure 2: Flowchart of step-by-step development of the applied statistical models
Source: own work

Firstly, the predictor of which the influence is measured is included in the univariable regressions (Box 1 – Figure 2). Secondly, the other predictor variables are added in the multivariable regressions (Box 2 – Figure 2). Thirdly, the adjusted multivariable models are regressed by adding the control variables (Box 3, 4 & 5 – Figure 2). The adjusted multivariable models are then calculated in three different steps. Firstly, control variables related to the particular characteristics are added. Secondly, control variables regarding environmental awareness are added. Finally, the other control characteristics are added. Summary stats for the control variables are shown in Appendix 3. All results from the univariable, multivariable, and adjusted multivariable models are presented in Appendix 6. The results for the multivariable model, including all predictors, and the third adjusted multivariable model, including all control variables, are presented in this chapter (Table 8: the dwelling characteristics; Table 9: socio-economic characteristics; Table 10: socio-demographic characteristics). As post estimation tests, Wald tests – to test the significance of individual predictors to the model – and Likelihood-ratio tests – to assess the goodness of fit of different models – are performed.

5.1 Dwelling characteristics

The predictor *dwelling type* shows multiple significant associations in the univariable and multivariable model. For the categories flat/apartment and terraced at a significance level of $p < 0.01$ in the dependent variable category don't know and for the flat/apartment at a level of $p < 0.01$ and $p < 0.05$ for terraced in the dependent variable category no. The results for the predictor *construction period* and no possibility to apply for EER subsidies show various significant results. For the predictor category 1970 – 1979 a significant positive association is measured at a level of $p < 0.05$ in the univariable model and $p < 0.1$ in the multivariable model. Further significant positive associations are found for the predictor category 1980 – 1989 and > 1990 in both the univariable and multivariable model at a significant level of $p < 0.01$. In the uni- and multi- variable models for don't know if it is possible to apply for EER subsidy similar results are founded. The category 1980 – 1989 shows a positive association at level of $p < 0.01$ in the univariable model, respectively $p < 0.05$ in the multivariable model. Finally, the category > 1990 shows a positive association at a level of $p < 0.1$ in the univariable model, and no significant result in the multivariable model.

Focusing on the results of the adjusted multivariable models the results are in line with the univariable and multivariable model results, leading to thirteen significant outcomes (Table 8). For the predictor *dwelling type* three significant results are measured in the adjusted multivariable model. The significant OR for no possibility to apply for EER subsidies in the predictor category flat/apartment is 2.42 times the odds of the possibility to apply for EER subsidies in the category detached, indicating a significant positive association. The result is significant at a level of $p < 0.01$. The OR for terraced (1.22) is indicating a positive association as well but changed from significant in the multivariable model to insignificant in the adjusted multivariable model. In the dependent variable category don't know if it is

possible to apply the significant the ORs in the predictor category flat/apartment and terraced are 2.67 and 1.28 times the odds of the possibility to apply for EER subsidies in the category detached. Both ORs indicate a significant positive association at a level of $p < 0.01$ for flat/apartment and $p < 0.1$ for terraced. The predictor category other types is not discussed since these are a combination of building types and therefore it is not possible to make any statements regarding this category. During the process to come to develop the model from univariable to adjusted multivariable model by adding the different predictor and control variables, the model stayed more or less robust. Looking at the results of the adjusted multivariable model for the predictor *construction period* five significant results are measured. Important to mention is that during the execution of the adjusted multivariable model the control variable EPC was deleted from the models due to high collinearity with the predictor *construction period*. The significant ORs for no possibility to apply for EER subsidies in the predictor categories 1970 – 1979, 1980 – 1989 and after 1990 are 1.34, 1.69 and 1.87 times the odds of a possibility to apply for EER subsidies in the category construction period before 1945. The measured positive associations are significant at a level of $p < 0.05$ for the category 1970 – 1979 and a level of $p < 0.01$ for both 1980 – 1989 and > 1990. Noticeable is that the ORs are increasing as the dwelling has a more recent construction period. Similar results are found for the don't know if it is possible to apply for EER subsidies. The significant ORs for don't know if it is possible to apply for EER subsidies in the predictor category 1980 – 1989 and after 1990 are 1.55 and respectively 1.49 times the odds of a possibility to apply for EER subsidies in the category before 1945. The results show positive associations at a level of $p < 0.05$ for both predictor categories. During the process from the univariable to the adjusted multivariable model the model stayed, with exception of control variable EPC, more or less robust.

Table 8: Results Multinomial Logistic Regression for dwelling characteristics.
Source: Own work.

Dependent variable	Predictors	Multivariable model[1]	Adjusted multivariable model[2]
	Type of dwelling (ref. detached)		
No	Flat / apartment	2.58 (0.64)***	2.42 (0.65)***
	Terraced	1.31 (0.16)**	1.22 (0.16)
	Semi – detached	0.96 (0.13)	0.93 (0.13)
	Other types	0.92 (0.22)	0.95 (0.24)
Don't know	Flat / apartment	3.02 (0.75)***	2.67 (0.70)***
	Terraced	1.42 (0.17)***	1.28 (0.17)*
	Semi – detached	1.03 (0.14)	0.99 (0.14)
	Other types	0.91 (0.22)	0.97 (0.24)
	Number of observations	11,179	11,179
	Wald[3]	111.59 (14)***	179.05 (36)***

	Likelihood ratio[3]	94.16 (8)***	68.53 (22)***
	Construction period (ref. before 1945)		
No	1945 - 1959	1.08	1.06
		(0.18)	(0.17)
	1960 - 1969	1.01	1.02
		(0.14)	(0.15)
	1970 - 1979	1.27	1.34
		(0.17)*	(0.18)**
	1980 - 1989	1.61	1.69
		(0.28)***	(0.30)***
	> 1990	1.72	1.87
		(0.32)***	(0.36)***
Don't know	1945 - 1959	0.96	0.94
		(0.15)	(0.15)
	1960 - 1969	0.89	0.9
		(0.13)	(0.13)
	1970 - 1979	1.05	1.14
		(0.14)	(0.15)
	1980 - 1989	1.45	1.55
		(0.25)**	(0.27)**
	> 1990	1.35	1.49
		(0.25)	(0.29)**
	Number of observations	11,179	11,179
	Wald[3]	132.49(18)***	184.25(36)***
	Likelihood ratio[3]	98.59 (8)***	67.55(20)***

Note: Table shows odds ratios, standard errors in parentheses and significant levels * p < 0.1; ** p < 0.05; *** p < 0.01
[1]The multivariable model controls for the predictors, construction period (for type dwelling), type dwelling (for construction period), (log) net income, education, and age
[2]The adjusted multivariable model controls for the other four predictor variables and the control variables: number of rooms, dwelling surface, mortgage debt, WOZ value, health, household composition, household size, household attitude towards livable earth, energy efficient dwelling, willingness to adopt EERs, EPC (latest is excluded for construction period)
[3]In parentheses the degrees of freedom

5.2 Socio-economic characteristics

The results of the univariable and multivariable logistic models show a significant negative association between the predictor category middle level of education and no possibility to apply for EER subsidies. The OR is significant at a level of $p < 0.1$. Although the model stays more or less robust when adding more variables in the multivariable model, it does lose its significance. The predictor variable *net income* shows in the multivariable logistic regression model a positive significant association with the category no possibility to apply for EER subsidies. It is significant at a level of $p < 0.1$.

Looking at the results from the adjusted multivariable model (Table 9), only one category in predictor *education* has significant results and no significant results are found in the *net income* predictor. For the significant OR the odds of no possibility to apply for EER subsidies in the predictor category middle education are 0.82 times the odds of the possibility to apply for subsidies in the category high education. The negative association shows that for every increase in the category no the number of households with a middle education, compared to high education, will decrease.

Table 9: Results multinomial logistic regression for socio-economic characteristics.
Source: Own work.

Dependent variable	Predictors	Multivariable model[1]	Adjusted multivariable model[2]
	Education (ref. high)		
No	Low	0.85	0.81
		(0.11)	(0.11)
	Middle	0.84	0.82
		(0.09)	(0.10)*
	Unknown	*0.68*	*0.65*
		(0.23)	*(0.22)*
Don't know	Low	1.14	1.05
		(0.15)	(0.14)
	Middle	1.01	0.98
		(0.11)	(0.11)
	Unknown	*1.1*	*1.03*
		(0.36)	*(0.34)*
	Number of observations	11,179	11,179
	Wald[3]	143.12(14)***	200.30(32)***
	Likelihood Ratio[3]	100.99(8)***	58.99(18)***
No	**(log) net income**	1.22	1.12
		(0.12)*	(0.14)
Don't know	(log) net income	0.996	0.98
		(0.10)	(0.12)
	Number of observations	11,179	11,179
	Wald[3]	123.94(10)***	191.33(32)***
	Likelihood Ratio[3]	93.78(8)***	68.66(22)***

Note: Table shows odds ratios, standard errors in parentheses and significant levels * p < 0.1; ** p < 0.05; *** p < 0.01
[1]The multivariable model controls for the predictors (log) net income (for education), education (for (log) net income), type dwelling, construction period and age
[2]The adjusted multivariable model controls for the other four predictor variables and the control variables: number of rooms, dwelling surface, EPC, mortgage debt, WOZ value, health, household composition, household size, household attitude towards livable earth, energy efficient dwelling, and willingness to adopt EERs
[3]In parentheses the degrees of freedom

5.3 Socio-demographic characteristics

Regarding *age*, the results of the univariable and multivariable models show significant positive associations for the category no possibility to apply for EER subsidies and the predictor categories 55 – 64 years and > 65 years. The robustness of the model is however different between the categories. The category 55 – 64 years is more or less robust if more variables are added to the model. The category > 65 years is less robust. The odds ratio changes from 1.42 in the univariable model to 1.58 in the multivariable model. The level of significant also increased from $p < 0.05$ to $p < 0.01$.

When analyzing the result for the adjusted multivariable predictor *age*, categorized under socio-demographic characteristics, two significant positive associations are measured (Table 10). Associations remain in line with the univariable and multivariable models. The odds of no possibility to apply for EER subsidies at the age of 55 until 64 years are 1.4 times the odds compared to the possibility to apply for subsidies for EERs in the age category of < 34 years. This result is significant at a level of $p < 0.1$. The odds of no possibility to apply for subsidies for EERs in the age category > 65 years are 1.61 times the odds compared to the possibility to apply for subsidies for EERs in the age category of < 34 years.

This result is significant at a level op $p < 0.1$ and $p < 0.05$. The predictor categories 35 – 44 years and 45 – 54 years for no possibility to apply for EER do show positive ORs but are not significant. All predictor categories for don't know if it is possible to apply for EER subsidies are not significant. The ORs fluctuate around 1 which means that there is almost no difference between the occurrence of a household saying that there is a possibility to apply for EERs and that they don't know if it is possible. Therefore, the model is more or less robust.

Table 10: Results multinomial logistic regression for socio-demographic characteristics.
Source: Own work.

Dependent variable	Predictor	Multivariable model[1]	Adjusted multivariable model[2]
	Age (ref. < 34 years)		
No	35 - 44 years	1.27	1.19
		(0.22)	(0.21)
	45 - 54 years	1.18	1.15
		(0.19)	(0.19)
	55 - 64 years	1.37	1.40
		(0.22)*	(0.24)*
	> 65 years	1.58	1.61
		(0.25)***	(0.29)***
Don't know	35 - 44 years	1.18	1.08
		(0.20)	(0.18)
	45 - 54 years	1.06	0.99
		(0.17)	(0.16)
	55 - 64 years	1.09	1.02
		(0.18)	(0.17)
	> 65 years	1.19	1.07
		(0.19)	(0.18)
	Number of observations	11,179	11,179
	Wald[3]	126.14(16)***	193.39(38)***
	Likelihood Ratio[3]	106.34(8)***	68.56(22)***

Note: Table shows odds ratios, standard errors in parentheses and significant levels * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.
[1]The multivariable model controls for the predictors (log) net income, education, type dwelling, and construction period.
[2]The adjusted multivariable model controls for the other four predictor variables and the control variables: number of rooms, dwelling surface, EPC, mortgage debt, WOZ value, health, household composition, household size, household attitude towards livable earth, energy efficient dwelling, and willingness to adopt EERs.
[3]In parentheses the degrees of freedom

6. DISCUSSION

Various studies found evidence for the influence of different dwelling-, socio-economic- and socio-demographic- household characteristics on the ability to adopt EERs. The major body of literature focuses on the direct association between household characteristics and the adoption of EERs. Less is known about the associations between financial incentives such as subsidies to stimulate EER adoption and household characteristics. This study focuses on the associations between household characteristics and subsidies for EERs in a Dutch context. The main differentiator of this study is that it focuses on defining the characteristics of households that in their perception could not or did not know whether it was possible to apply for EER subsidies. This is an uncommon approach since existing literature focuses

mainly on those who applied for financial incentives and which households adopt EERs. This point of view adds to the academic debate on the heterogeneity among households and how this influences their energy efficient attitude and behavior. Five hypotheses are formulated to measure assumed associations between five household characteristics and the possibility to apply for subsidies. Through a multinomial logistic regression the results are calculated (Appendix 6).

In the category dwelling characteristics the results for the adjusted multivariable model (Table 7) for *dwelling type* show significant positive associations. Associations between dwelling types that are more connected to neighboring dwellings (ref: detached) and the dependent variable categories no and don't know if it is possible to apply for EER subsidies (ref: yes). The findings in the category don't know are more or less in line, due to two positive significant results, with the category no with only one significant result. The results indicate that the dwellings that are more connected to neighboring dwellings are positively associated with households that don't know if they can apply for subsidies and households who think there is no possibility to apply. Placing these results in a broader academic picture the results are more or less in conformity with the in chapter 3 discussed literature. Schleich's (2019) article, which is only to a limited degree comparable because he used a binary variable (detached or reference: not), showed that this variable was significant. Trotta (2018) added four categories for dwelling type, the same as used in this study, and showed that households living in detached properties were more likely to adopt EERs and households in flat/apartments were less likely. The main assumption of Schleich (2019) and Trotta (2018) that households with (more) detached dwelling types are more likely to adopt EERs are in line with the findings of this study. In other words, households that own a dwelling that is more connected to neighboring dwellings are less likely to apply for subsidies. To explain the current findings multiple arguments are possible. One could argue that it is more difficult for households to adopt EERs because the investment and installation process is complex due to a higher number of involved stakeholders (e.g. VvE other neighbors). In line with this complex situation it could result in lesser degree of awareness and attention for the adoption of possible available subsidies. A further explanation, an argument that is used in literature as well (Schleich, 2019; Trotta, 2018), is that the variable *dwelling type* interacts with *net income*. Lower net income households living in flat/apartment are compared to higher net income households in detached dwelling types less aware of possible subsidies. This study is limited in further explaining possible interactions because no interaction measures are performed. Both arguments on the complexity to implement EERs and interactions are starting points for future research.

The results for the adjusted multivariable model (Table 8) for *construction period* show significant positive associations between the recent construction periods (ref: before 1945) and the dependent categories no and don't know if it is possible to apply for EER subsidies (ref: yes). The findings in this study support the second hypothesis that assumes a positive association for the no and don't know category in the dependent variable. Worth noting within the results of the category no possibility to apply is that the ORs increase when the construction period is more recent. In the category

don’t know the ORs are similar but do not increase per predictor category. Placing these results in the context of existing literature, the results show similarities with the findings of Schleich (2019) and Michelsen & Madlener (2012). Schleich (2019) conducted a cross-European study per country (excl. the Netherlands) which shows different results per country. Noticeable is however that all western European countries (Sweden, Germany, France, UK) in his study show the positive association compared to the other countries (Italy, Poland, Estonia, Romania). Although it is difficult to compare, one could argue that the findings of this study more or less follow the results of Schleich’s (2019) western European countries results. Michelsen & Madlener (2012) found comparable evidence in a German context in which they conclude that homeowners with recent building years are less interested in investing in energy efficient heating systems. Different from this study is that Schleich (2019) and Michelsen & Madlener (2012) used actual building years instead of periods and were therefore better able to determine the actual associations. Coming to the main argument for building age, both Schleich (2019) and Michelsen & Madlener (2012) suggest that building age can be used as a proxy for the current energy efficient state for a building. Connecting their suggestions to the results of this study, one could argue that households with recent building years are less interested in subsidies compared to older building periods, because their buildings are in a better state already. However this argument seems to be too limited when looking at the actual significant building periods defined in this study. For example, it is likely that dwellings in the period 1970-1979 are not on the most energy efficient state yet. Future research could focus on comparing building age to actual adopted EERs to assess whether this result and previous results from literature are accurate. Worth examining could be to what extent the perception of the owner-occupier households with dwellings with recent buildings years is in line with the actual energy efficiency of their dwellings.

Coming to the socio-economic characteristics the predictor *education* show in the adjusted multivariable model (Table 9) one significant negative association between the middle level of education (ref: high) and the dependent variable category no possibility to apply for subsidies. The result indicate an inverse association, meaning middle level education (ref: high) is 0.82 times less likely to cause change in the dependent variable category no possibility to apply (ref: yes). This result is not in line with the third hypothesis and partially in line with the discussed literature. Trotta (2018) did not find evidence for a significant influence of education. Different from this study is that Trotta (2018) used a binary variable in which he differentiated between everyone with a BA and the rest. Different from Trotta’s (2018) approach, Michelsen & Madlener (2012) differentiated on two different levels as well (university level or not) and found positive significant evidence for the influence of education. Studies more similar to this study containing more predictor categories (Mills & Schleich, 2012; Sardianou & Genoudi, 2013) present significant evidence. The main difference from this study and the discussed literature is that the assumption in this study has been turned around. Meaning, all discussed authors expect associations between high education levels and EER adoption and do not focus on the low education groups, this study assumes low education in the don’t know if it is possible to apply category with high education as

a reference category. However, this assumed association cannot be substantiated with the evidence found for this study. Finally, an explanation for the results for *education* is the sample distribution. Looking at the cross tabs (Appendix 3) high education contains 38% of the sample and low education 26%. One could argue that households with higher education are more likely to own a dwelling, resulting in an over representation in the sample used for this study.

The predictor *net income* only show – in the multivariable model (Table 9) – a positive association in the dependent variable category no possibility to apply for subsidies. In the adjusted multivariable model an insignificant positive result in the category no possibility to apply and a very small insignificant negative association was measured for the category don't know if it is possible to apply. The fourth hypothesis assumed a negative association between both no and don't know categories and is therefore not met. Especially notable is the result of the positive association. The hypothesis assumed that the higher net income groups are represented in the yes category, however, the results show that the no category increases if net income increases. Looking at the literature the results for this study are especially significant since literature showed contrary results. Sardianou & Genoudi (2013) show that perceptions regarding the adoption of EERs among household with higher net income are different from lower net income classes. Regarding the actual actions to adopt, Schleich (2019) found evidence that in seven of his eight assessed countries the lowest net income group showed negative significant results, indicating that this group is adopting less EERs. Trotta (2018) pointed out that three of four of the by him defined highest net income groups had positive significant associations. However, these assumptions translated into negative associations in the fourth hypothesis are not observable in the categories don't know if it is possible to apply and no possibility to apply, which even shows an insignificant positive association. Important to mention is that the above articles used binary and categorial variables to measure the net income. This study used a continuous variable for net income. Nevertheless, based on the findings it can be argued that net income has a limited influence on the application for EER subsidies. Since existing literature differs from these results it is difficult to explain this outcome. The findings therefore underline the importance to further look into the association between net income and EER subsidies.

Finally the socio-demographic characteristic *age* show in the adjusted multivariable model (Table 10) significant positive association for the two highest age classes. The results indicate that higher age (ref: homeowners < 34 year) are likely to cause change in the dependent variable no possibility to apply (ref: yes). One could argue that older homeowners tend to have the opinion that it is not possible to apply for EER subsidies. This result is in line with the fifth hypothesis based on the assumption that older homeowners have in their own perspective a better understanding of the possibilities to apply or not apply for EER subsidy or are not interested in subsidies. It is noticeable that the findings are in line with the hypothesis and the dependent variable category don't know if it is possible to apply shows similar but insignificant ORs. However it is difficult to relate the findings to the discussed literature since conclusions in literature are widely scattered. Sardiano & Genaudi (2013) who focused on

financial incentives and household characteristics show that middle aged groups (36–50 years) are most stimulated by subsidies (ref: youngest group). Mills & Schleich (2012) contend that the younger and middle age groups are also significantly associated with EER adoption. They explain that younger groups are more aware and older groups are less likely to adopt since they cannot profit optimally from the EERs. Contrary Trotta (2018) and Schleich (2019) argue that the middle and older age categories are more likely to adopt EERs because of the combination of awareness and financial resources that are lacking among the younger groups. It is difficult to place the results within the academic debate. The results indicate that older age groups are unambiguous in their choice for no possibility to apply for EER subsidies but the underlying reasons are debatable. Especially given the widely varying arguments in scientific literature. For instance, are older homeowners, as Mills & Schleich (2012) indicate, less interested in subsidies because they do not want to adopt EERs, or do they, as Trotta (2018) and Schleich (2019) mention, have the financial resources and are therefore less interested in subsidies. A further explanation of these results is if the older age groups in this study are lacking awareness regarding the possibility to apply for subsidies. The findings and limitations to explain these findings for the characteristic age underline the importance for future research concerning this topic.

7. CONCLUSIONS & RECOMMENDATIONS

6.1 Conclusion

The aim of this study is to evaluate the application process for subsidy in the first round SEEH policy by exploring possible associations between household characteristics of households who in their perception could not apply or did not know whether they could apply for subsidies. By means of a multinomial logistic regression model – controlling for different other contextual household characteristics – the associations for the characteristics *dwelling type, construction period, education, net income* and *age* have been explored. The characteristic *dwelling type* presents positive associations between a higher connectedness to a neighboring dwelling (flat/apartment and terraced dwellings) and no and don't know if it is possible to apply for SEEH subsidies. Since these dwelling types are more connected to neighboring dwellings it is probably more difficult to coordinate the EER adoption. This could result in less attention for possible subsidy adoption and influencing the perceptions of owner-occupiers regarding the subsidies. The characteristic *construction period* shows further positive associations between the more recent construction periods and no and don't know if it is possible to apply for SEEH subsidies. These results indicate that the perception of owner-occupiers regarding possible subsidy is influenced by the building age of their dwelling. An explanation could be that owner-occupiers hold a perception that their dwelling is energy efficient because it was built recently, which is affecting their perception on possible subsidy adoption. Noticeable is that the results of this study show significant associations between the construction period 1970 and onwards and no and don't know if it

is possible to apply for SEEH subsidies. Questionable is whether these dwellings – built 40 - 50 years ago – are at their highest energy efficiency level already. This could suggest that owner-occupiers have some kind of false perception regarding the actual energy efficiency of their dwelling. The assumedly positive association for the characteristic *education* is not observed. In fact, a negative association exists between middle level of education and no possibility to apply for SEEH subsidies. For the fourth characteristic *net income* no significant results occur. The fifth and final household characteristic *age* does show positive associations between the two oldest age groups and no possibility to apply for SEEH subsidies. Explanations for these findings could be that older age groups have the financial means – compared with younger age categories – to adopt EERs or older age groups have less focus on adopting EERs. In general, the results of this study indicate that different contextual household characteristic are associated with the possibility to apply for subsidies. This study is an extension of the current academic literature on the heterogeneity among households in subjects regarding energy efficient retrofits and subsidies in real estate research.

6.2 Implications for real estate practice

Placing the conclusions in a societal perspective, the results of this study are relevant for residential real estate policy makers from national to local governments. The observations indicate that the application process for the first round SEEH subsidies in the Netherlands is associated with different contextual household characteristics. One could argue that the main significant findings in this study show that more connected dwelling types, recent construction periods, and older aged households are characteristics that need to be addressed in future policy development. However, as discussed in the previous discussion chapter, this study does not give insights into further underlying explanations for the results. Therefore, the findings can be seen as starting point for policy maker to look further into these characteristics and better target specific groups of owner-occupiers in order to get all different household groups into the subsidy programs. Furthermore, the results can be seen as a critical review of the SEEH evaluation report (RVO, 2018). It emphasizes the importance of comprehensive research among the initial target group, not only among the households who used the subsidy.

The main implications and contribution of this study to society highlights that if the governmental policy makers want to stimulate, by means of subsidies, the owner-occupier households to adopt EERs, they need to create better insight into the heterogeneity of households. This could result in tailor-made policies and subsidies that are better focused on all households, represented in certain target groups. In general, acknowledgment to household heterogeneity in residential real estate policies for EERs could accelerate a broad adoption of EERs among households, accelerating the Dutch energy transition. Furthermore, this acknowledgment and inclusion in policies could be effective in other household related subsidies as well, possibly resulting in a more balanced distribution of governmental means among Dutch inhabitants. Finally, the results of this study underline the importance for comprehensive

evaluations of issued subsidy policies by the government. Evaluations could create insights into new starting points for new rounds of subsidies.

6.3 Strengths, limitations and recommendations for future research

The chosen research approach which is focused on the households who did not or in their perception could not apply for subsidies is a strength of this study. The majority of the existing research focused on the households who did apply for subsidies or adopt EERs and used these results as basis for assumptions regarding the households who did not apply for subsidies or adopt EERs. This study only focuses on the latter group. A further advantage of this study is the use of the WoON database. This database is highly valued and used by policy makers at different governmental levels as basis for future residential real estate related policy development. It is a reliable source of information, which contributes to the reliability of the findings in this study.

Apart from the strong points, it is important to also discuss the limitations of this study. The in this study included predictors and the control variables used present a static situation (visualized in Figure 1). Since the world is not static many more characteristics and issues outside of the conceptual model used could influence the outcomes of this study. Furthermore the influence of possible interactions between the predictors is also not addressed in this study. It was a deliberate choice not to include more predictors and interactions given the master thesis objective and time. A second limitation of this study was the data transformation process to come to the sample current used sample. As discussed in the fourth chapter there were four steps in which the sample size was reduced from around 67,000 observations to 11,179. This selection was necessary to accurately adjust the sample to the study aim, but at the same time reduces the explanatory power of the study because the author made adjustments to the sample. Moreover this limitation resulted in not including locational predictor variables, which could be a relevant differentiator for further policy development, due to a to low number of observations. A third limitation of this study is that the WoON-database could possibly limit certain included predictor variables. For example the predictors *construction period* and *age* are classified in WoON in a concise group of periods. By looking into the possibilities to combine the WoON database with other public sources such as CBS data these data points could have been added in as more categories or even as continuous predictor variables. Furthermore, by adding other data more control variables could have been added. A fourth limitation is that the predictors *net income, education,* and *age* are based on the respondent, and therefore says less about the complete household. For example, the respondent could have a low education, but his or her spouse a high education, and vice versa, giving a different picture. In this study the information of the respondent is used as a proxy for the whole household. A fifth limitations of this study is the difficulties in doing a follow up research. A follow up could be relevant to see if after policies are changed, changes do occur. However, the WoON database does not contain panel data. For a follow-up specific data from the same households is necessary. Finally, this study is limited in explaining differences between the categories no and don’t know since

a model in which these differences are explored is not added. Although this model and explanations would not have been part of this studies scope it would probably have been an interesting extension to the current findings.

The above described limitations of this study are starting points for future research. A larger sample including more detailed predictors could lead to better insights, choosing a different database could lead to better follow-up studies, and including more predictors and control variables could lead to a more substantiated outcome. Moreover, comparing the no and don't know categories would probably lead to further insights into the influencing household characteristics. The main advice for future research, especially given the increasing governmental focus on sustainably in residential real estate, is to focus on further exploring the type of associations between various household characteristics and the ability of households to apply for subsidies and adopt EERs. Heterogeneity of households should be given more importance in scientific research on policy development for residential real estate.

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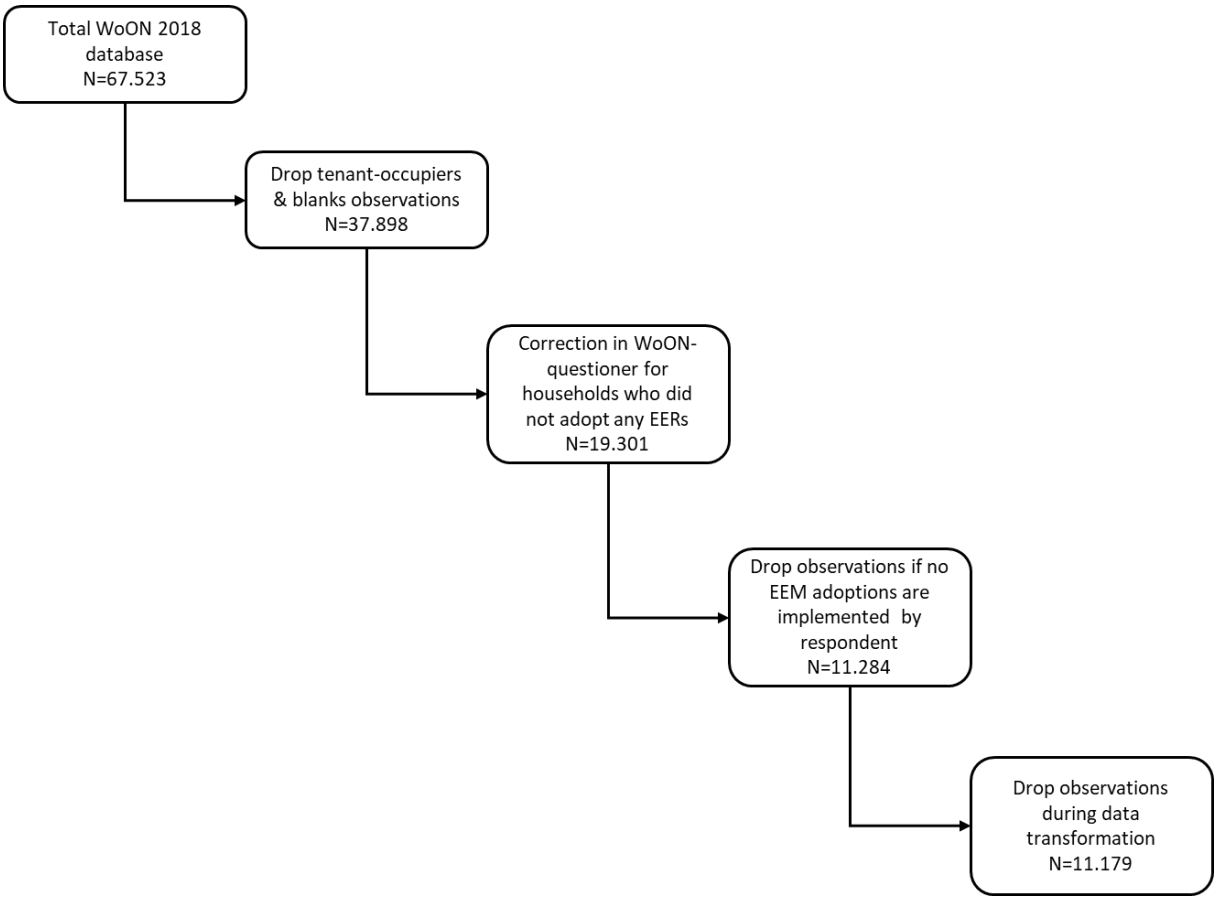
Appendix 1: Operationalization of dependent variable

Below figure shows a flowchart regarding the taken steps towards the final sample of this research.



Appendix 2: Data management of predictors and control variables

Predictors

Variable	Variable Type	Transformation	Description	Categories
Dwelling characteristics				
Type Dwelling	Categorial	Combining three different categories into one due to limited observations.	Selection on the type of dwelling based on the level of enclosure by neighboring dwellings.	1: Flat/apartment; 2: Terraced; 3: Semi-detached; 4: Detached; 5: Other types.
Construction Period	Categorial	Combining three different categories into one category due to limited observations.	Six categories to define the construction period of a dwelling.	1: Before 1945; 2: 1945 – 1959; 3: 1960 – 1969; 4: 1970 – 1979; 5: 1980 – 1989; 6: 1990 and upward.
Socio-economic characteristics				
Education	Categorial	No relevant transformation actions.	Three levels of education from low to high.	1: Low; 2: Middle; 3: High; 4: Unknown.
Net income	Continuous	Drop categories with no registered net income. Natural log to correct for outliers.	The net net income of the households in 2018 according to the CBS standards.	No categories.
Socio-demographic characteristics				
Age	Categorial	Combining the two lowest and two highest categories due to limited observations.	Five age categories on the age of the respondents of the WoON survey.	1: 34 years and younger; 2: 35 – 44 year; 3: 45 – 54 year; 4: 55 – 64 year; 5: 65 and older.

Control Variables

Variable	Variable Type	Transformation	Description	Categories
Dwelling characteristics				
Number of Rooms	Categorial	No transformation.	Number of rooms in dwelling of respondent.	1: 1-2 rooms; 2: 3 rooms; 3: 4 rooms; 4: 5 rooms; 5: 6 and more rooms.
Dwelling Surface	Categorial	Transfer missing values into numerical value and label unknown and combining the first two categories due to limited observations.	Seven categories regarding the surface of the dwelling.	1: < 70 m2; 2: 70 – 89 m2; 3: 90 – 119 m2; 4: 120 – 149 m2; 5: 150 – 199 m2; 6: > 200 m2; 7: Unknown.
EPC	Categorial	Transfer missing values into numerical value and label unknown.	Energy Performance Certificates (EPC) are an indication to the energy efficiency of the subject dwelling. Reference is the 2018 RVO data.	1: A; 2: B; 3: C; 4: D; 5: E; 6: F; 7: G;

				8: Unknown.
Socio-economic characteristics				
Mortgage Debt	Continuous	Correct for outliers above 1 million euros (21 observations).	The variable entails the amount of mortgage debt if the respondents have a debt. No debts are registered as zero.	No categories.
WOZ – value	Continuous	Correct for outliers above 1 million euros (46 observations).	Through the 'Wet Waardering Onroerende Zaken' (WOZ) all valuations of real estate in the Netherlands is Managed. Reference date is 01-01-2016.	No categories.
Socio-demographic characteristics				
Health	Categorial	No transformation	Five categories on the perception of health among the respondents.	1: Very good; 2: Good; 3: It's okay; 4: Sometimes; good, sometimes bad; 5: Bad.
Household Composition	Categorial	No transformation	Five categories on the composition of households.	1: One-person household; 2: Couple; 3: Couple and child(ren); 4: One parent family; 5: Not family household.
Household Size	Categorial	No transformation	Number of persons that are part of a household.	1: 1 person; 2: 2 persons; 3: 3 persons; 4: 4 persons; 5: >5 persons.
Environmental awareness				
Livable Earth	Categorial	Combine the two both outside categories of the 5 step Likert-scale to create a 3 step scale to correct for limited observations.	The perception of households regarding the impact of energy efficient dwellings on the livability of the earth.	1: Agree; 2: Neutral; 3: Disagree.
Energy Efficient Dwelling	Categorial	Combine the two both outside categories of the 5 step Likert-scale to create a 3 step scale to correct for limited observations.	The perception of households on the energy efficiency of their dwelling.	1: Agree; 2: I do not agree, but also not disagree; 3: Disagree.
Willingness to Adopt EERs	Categorial	No transformation	The willingness of households to adopt and execute EERs. The yes question is separated in whether households can retain the EER costs.	1: Yes, but only if I can recoup the costs; 2: Yes, even if I cannot recoup the costs; 3: No; 4: Don't know.

Appendix 3: Summary statistics categorial and continuous independent and control variables

Cross tabulations predictors

	Possibility to apply for subsidy			
	Yes	**No**	**Don't know**	**Total**
	502	5045	5632	11179
Dwelling Characteristics				
Dwelling type				
N Flat/apartment	20	412	524	956
%	4.0%	8.2%	9.3%	8.6%
N Terraced	208	2314	2659	5181
%	41.4%	45.9%	47.2%	46.3%
N Semi-detached	122	1022	1129	2273
%	24.3%	20.3%	20.0%	20.3%
N Detached	129	1132	1141	2402
%	25.7%	22.4%	20.3%	21.5%
N Other types/Unknown	23	165	179	367
%	4.6%	3.3%	3.2%	3.3%
Construction period				
< 1945	159	1304	1612	3075
%	31.7%	25.8%	28.6%	27.5%
1945 - 1959	58	511	580	1149
%	11.6%	10.1%	10.3%	10.3%
1960 - 1969	89	758	858	1705
%	17.7%	15.0%	15.2%	15.3%
1970 - 1979	110	1237	1266	2613
%	21.9%	24.5%	22.5%	23.4%
1980 - 1989	47	662	764	1473
%	9.4%	13.1%	13.6%	13.2%
> 1990	39	573	552	1164
%	7.8%	11.4%	9.8%	10.4%
Socio-economic characteristics				
Education				
Low	127	1254	1579	2960
%	25.3%	24.9%	28.0%	26.5%
Medium	176	1610	1908	3694
%	35.1%	31.9%	33.9%	33.0%
High	188	2093	2010	4291
%	37.5%	41.5%	35.7%	38.4%
Unknown	11	88	135	234
%	2.2%	1.7%	2.4%	2.1%
Socio-demographic characteristics				
Age				
< 34 year	74	596	783	1453
%	14.7%	11.8%	13.9%	13.00%
35 - 44 year	82	843	994	1919
%	16.3%	16.7%	17.6%	17.17%
45 - 54 year	114	1051	1200	2365
%	22.7%	20.8%	21.3%	21.16%
55 - 64 year	106	1112	1154	2372
%	21.1%	22.0%	20.5%	21.22%
> 65 year	126	1443	1501	3070
%	25.1%	28.6%	26.7%	27.46%

Cross tabulations control variables

	Possibility to Apply for subsidies			
	Yes	**No**	**Don't know**	**Total**
Dwelling characteristics				
Dwelling Surface				
<70m2	8	142	208	358
%	1.6%	2.8%	3.7%	3.2%
70-89m2	36	390	556	982
%	7.2%	7.7%	9.9%	8.8%
90-119m2	145	1546	1870	3561
%	28.9%	30.6%	33.2%	31.9%
120-149m2	136	1464	1432	3032
%	27.1%	29.0%	25.4%	27.1%
150-199m2	102	894	941	1937
%	20.3%	17.7%	16.7%	17.3%
>200m2	67	536	530	1133
%	13.3%	10.6%	9.4%	10.1%
Unknown	8	73	95	176
%	1.6%	1.4%	1.7%	1.6%
Energy Performance Certificate				
A	6	106	94	206
%	1.2%	2.1%	1.7%	1.8%
B	26	349	360	735
%	5.2%	6.9%	6.4%	6.6%
C	122	1562	1748	3432
%	24.3%	31.0%	31.0%	30.7%
D	78	639	605	1322
%	15.5%	12.7%	10.7%	11.8%
E	33	361	448	842
%	6.6%	7.2%	8.0%	7.5%
F	90	910	1080	2080
%	17.9%	18.0%	19.2%	18.6%
G	129	906	1092	2127
%	25.7%	18.0%	19.4%	19.0%
Unknown	18	212	205	435
%	3.6%	4.2%	3.6%	3.9%
Socio-Demographic Characteristic				
Health				
Very Good	126	1149	1174	2449
%	25.1%	22.8%	20.8%	21.9%
Good	299	3004	3355	6658
%	59.6%	59.5%	59.6%	59.6%
It's okay	44	601	703	1348
%	8.8%	11.9%	12.5%	12.1%
Sometimes good, sometimes bad	23	212	287	522
%	4.6%	4.2%	5.1%	4.7%
Bad	10	79	113	202
%	2.0%	1.6%	2.0%	1.8%
Household Composition				
One-person household	101	789	1112	2002
%	20.1%	15.6%	19.7%	17.9%
Couple	190	2190	2160	4540
%	37.8%	43.4%	38.4%	40.6%
Couple & Child(ren)	183	1833	2033	4049
%	36.5%	36.3%	36.1%	36.2%

One parent family	17	177	224	418
%	3.4%	3.5%	4.0%	3.7%
Not family household	11	56	103	170
%	2.2%	1.1%	1.8%	1.5%
Household Size				
1 person	101	789	1112	2002
%	20.1%	15.6%	19.7%	17.9%
2 persons	204	2310	2318	4832
%	40.6%	45.8%	41.2%	43.2%
3 persons	84	735	824	1643
%	16.7%	14.6%	14.6%	14.7%
4 persons	77	855	1000	1932
%	15.3%	16.9%	17.8%	17.3%
5 or more persons	36	356	378	770
%	7.2%	7.1%	6.7%	6.9%
Environmental Awareness				
Livable earth				
Agree	447	4443	4909	9799
%	89.0%	88.1%	87.2%	87.7%
Neutral	37	479	601	1117
%	7.4%	9.5%	10.7%	10.0%
Disagree	18	123	122	263
%	3.6%	2.4%	2.2%	2.4%
Perception of energy efficient dwelling				
Agree	230	2162	2180	4572
%	45.8%	42.9%	38.7%	40.9%
Neutral	164	1813	2285	4262
%	32.7%	35.9%	40.6%	38.1%
Disagree	108	1070	1167	2345
%	21.5%	21.2%	20.7%	21.0%
Willingness to invest in EERs				
Yes, but only if I can recoup the costs	253	2575	2773	5601
%	50.4%	51.0%	49.2%	50.10%
Yes, even if I cannot recoup the costs	132	869	905	1906
%	26.3%	17.2%	16.1%	17.05%
No	67	848	771	1686
%	13.3%	16.8%	13.7%	15.08%
Don't Know	50	753	1183	1986
%	10.0%	14.9%	21.0%	17.77%

Variable	N	Mean	Std. Dev.	Min	Max
Dwelling characteristics					
Number of Rooms	11,179	5.01	1.61	1	60
Socio-economic characteristics					
Mortgage Debt	11,179	€ 143,842.90	€ 129,670.80	€ -	€ 996,862.00
WOZ - Value	11,179	€ 269,095.30	€ 133,194.30	€ 16,365.00	€ 999,779.00

Appendix 4: Pearson correlation matrix for continuous predictor variables and control variables

	(log) net income	(log) rooms	WOZ value	Mortgage debt
(log) net income	1,0000			
(log) Rooms	0,2793	1,0000		
WOZ value	0.3820	0,3574	1,0000	
Mortgage debt	0,3822	0,1825	0,3199	1,0000

Appendix 5: Results variance inflation factor

Variable (dependent variable)	VIF	1/VIF
household size	2.96	0.338325
construction period	2.62	0.381127
EPC	2.60	0.384294
household composition	2.46	0.406307
WOZ value	1.77	0.566491
dwelling surface	1.73	0.578221
age	1.71	0.585543
debt mortgage	1.66	0.602965
(log) net income	1.61	0.623033
dwelling type	1.49	0.673063
(log) rooms	1.41	0.707267
(log) savings	1.23	0.814490
education	1.18	0.846497
energy efficiency	1.11	0.899832
health	1.10	0.909925
willingness to invest	1.09	0.917537
livable earth	1.03	0.975359
Mean VIF	**1.69**	

Appendix 6: Results multinomial logistic regression models

Results dwelling characteristics

		Univariable model[1]	Multivariable model[2]	Adjusted multivariable model 1[3]	Adjusted multivariable model 2[4]	Adjusted multivariable model 3[5]
	Type of dwelling (ref. detached)					
No	Flat / apartment	2.35	2.58	2.41	2.36	2.42
		(0.58)***	(0.64)***	(0.65)***	(0.63)***	(0.65)***
	Terraced	1.27	1.31	1.22	1.22	1.22
		(0.15)**	(0.16)**	(0.16)	(0.16)	(0.16)
	Semi-detached	0.95	0.96	0.93	0.93	0.93
		(0.13)	(0.13)	(0.13)	(0.13)	(0.13)
	Other types	0.82	0.92	0.97	0.97	0.95
		(0.20)	(0.22)	(0.24)	(0.24)	(0.24)
Don't know	Flat / apartment	2.96	3.02	2.63	2.55	2.67
		(0.72)***	(0.75)***	(0.70)***	(0.68)***	(0.70)***
	Terraced	1.45	1.42	1.27	1.26	1.28
		(0.17)***	(0.17)***	(0.17)**	(0.17)*	(0.17)*
	Semi-detached	1.05	1.03	0.97	0.98	0.99
		(0.14)	(0.14)	(0.13)	(0.13)	(0.14)
	Other types	0.89	0.91	1.003	0.996	0.97
		(0.21)	(0.22)	(0.25)	(0.25)	(0.24)
	Number of Observations	11,179	11,179	11,179	11,179	11,179
	Wald Test	18.67 (6)***	111.59 (14)***	120.12 (20)***	159.76 (26)***	179.05 (36)***
	LR		94.16 (8)***	8.18 (6)	48.71 (12)***	68.53 (22)***
	Construction period (ref. before 1945)					
No	1945 - 1959	1.07	1.08	1.06	1.08	1.06

		(0.17)	(0.18)	(0.17)	(0.18)	(0.17)
	1960 - 1969	1.04	1.01	0.998	1.03	1.02
		(0.15)	(0.14)	(0.14)	(0.14)	(0.15)
	1970 - 1979	1.37	1.27	1.3	1.34	1.34
		(0.18)**	(0.17)*	(0.17)*	(0.18)**	(0.18)**
	1980 - 1989	1.72	1.61	1.61	1.7	1.69
		(0.30)***	(0.28)***	(0.28)***	(0.30)***	(0.30)***
	> 1990	1.79	1.72	1.76	1.92	1.87
		(0.33)***	(0.32)***	(0.33)***	(0.37)***	(0.36)***
Don't know	1945 - 1959	0.99	0.96	0.94	0.96	0.94
		(0.16)	(0.15)	(0.15)	(0.15)	(0.15)
	1960 - 1969	0.95	0.89	0.88	0.91	0.9
		(0.13)	(0.13)	(0.12)	(0.13)	(0.13)
	1970 - 1979	1.14	1.05	1.07	1.13	1.14
		(0.15)	(0.14)	(0.14)	(0.15)	(0.15)
	1980 - 1989	1.60	1.45	1.46	1.57	1.55
		(0.28)***	(0.25)**	(0.25)**	(0.27)**	(0.27)**
	> 1990	1.40	1.35	1.38	1.54	1.49
		(0.26)*	(0.25)	(0.26)*	(0.29)**	(0.29)**
	Number of Observations	11,179	11,179	11,179	11,179	11,100
	Wald test	34.76 (10)***	132.49(18)***	139.64(22)***	179.96(28)***	184.25(36)***
	Likelihood ratio test		98.59 (8)***	6.74(4)	48.29(10)***	67.55(20)***

Note: Table shows odds ratios, standard errors in parentheses and significant levels * p < 0.1; ** p < 0.05; *** p < 0.01
1: Univariable model includes the only the predictor regression
2: Multivariable model adds other four predictors
3: Adjusted multivariable model 1 adds control variables for dwelling characteristics: dwelling surface, EPC, number of rooms
4: Adjusted multivariable model 2 adds for environmental awareness: perception on livable earth, perception of energy efficiency of dwelling, willingness to invest in EERs
5: Adjusted multivariable model 3 adds all other control variables: mortgage debt, WOZ value, health, household composition, household size

Results socio-economic characteristics

	Predictors	Univariable model	Multivariable model	Adjusted multivariable model 1	Adjusted multivariable model 2	Adjusted multivariable model 3
	Education (ref. high)					
No	Low	0.89	0.85	0.86	0.83	0.81
		(0.11)	(0.11)	(0.11)	(0.11)	(0.11)
	Middle	0.82	0.84	0.84	0.82	0.82
		(0.09)*	(0.09)	(0.10)	(0.10)	(0.10)*
	Unknown	0.72	0.68	0.65	0.63	0.65
		(0.24)	(0.23)	(0.22)	(0.21)	(0.22)
Don't know	Low	1.16	1.14	1.11	1.06	1.05
		(0.14)	(0.15)	(0.15)	(0.13)	(0.14)
	Middle	1.01	1.01	0.996	0.97	0.98
		(0.11)	(0.11)	(0.11)	(0.12)	(0.11)
	Unknown	1.15	1.1	1.04	0.98	1.03
		(0.37)	(0.36)	(0.34)	(0.32)	(0.34)
	Number of observations	11,179	11,179	11,100	11,100	11,100
	Wald test	42.96(6)***	143.12(14)***	144.25(18)***	182.58(24)***	200.30(32)***
	LR		100.99(8)***	1.16(4)	40.63(10)***	58.99(18)***
No	**(log) net income**	1.14	1.22	1.18	1.20	1.12
		(0.11)	(0.12)*	(0.14)	(0.14)	(0.14)
Don't know	(log) net income	0.91	0.996	1	1.03	0.98
		(0.09)	(0.10)	(0.11)	(0.12)	(0.12)
	Number of observations	11,179	11,179	11.100	11.100	11.100
	Wald test	30.40(2)***	123.94(10)***	124.93(14)***	165.28(20)***	191.33(32)***
	LR		93.78(8)***	0.97(4)	42.39(10)***	68.66(22)***

Note: Table shows odds ratios, standard errors in parentheses and significant levels * p < 0.1; ** p < 0.05; *** p < 0.01
1: Univariable model includes the only the predictor regression

2: Multivariable model adds other four predictors
3: Adjusted multivariable model 1 adds control variables for dwelling characteristics: mortgage debt, WOZ value
4: Adjusted multivariable model 2 adds for environmental awareness: perception on livable earth, perception of energy efficiency of dwelling, willingness to invest in EERs
5: Adjusted multivariable model 3 adds all other control variables: dwelling surface, EPC, number of rooms, health, household composition, household size

Results socio-demographic characteristics

	Predictors	Univariable model	Multivariable model	Adjusted multivariable model 1	Adjusted multivariable model 2	Adjusted multivariable model 3
	Age (ref. < 34 years)					
No	35 - 44 years	1.28	1.27	1.2	1.18	1.19
		(0.22)	(0.22)	(0.21)	(0.21)	(0.21)
	45 - 54 years	1.15	1.18	1.16	1.15	1.15
		(0.18)	(0.19)	(0.19)	(0.19)	(0.19)
	55 - 64 years	1.3	1.37	1.43	1.42	1.4
		(0.21)*	(0.22)*	(0.24)**	(0.24)**	(0.24)*
	> 65 years	1.42	1.58	1.66	1.63	1.61
		(0.22)**	(0.25)***	(0.25)***	(0.27)***	(0.29)***
Don't know	35 - 44 years	1.15	1.18	1.11	1.08	1.08
		(0.19)	(0.20)	(0.19)	(0.18)	(0.18)
	45 - 54 years	0.99	1.06	1.02	0.99	0.99
		(0.16)	(0.17)	(0.16)	(0.15)	(0.16)
	55 - 64 years	1.03	1.09	1.07	1.04	1.02
		(0.16)	(0.18)	(0.18)	(0.16)	(0.17)
	> 65 years	1.13	1.19	1.06	1.09	1.07
		(0.17)	(0.19)	(0.19)	(0.19)	(0.18)
	Number of observations	11,179	11,179	11,179	11,179	11,179
	Wald test	20.73(8)***	126.14(16)***	145.46(22)***	183.77(28)***	193.39(38)***
	LR		106.34(8)***	19.74(6)***	59.21(12)***	68.56(22)***

Note: Table shows odds ratios, standard errors in parentheses and significant levels * p < 0.1; ** p < 0.05; *** p < 0.01
1: Univariable model includes the only the predictor regression

2: Multivariable model adds other four predictors
3: Adjusted multivariable model 1 adds control variables for dwelling characteristics: health, household composition, household size
4: Adjusted multivariable model 2 adds for environmental awareness: perception on livable earth, perception of energy efficiency of dwelling, willingness to invest in EERs
5: Adjusted multivariable model 3 adds all other control variables: mortgage debt, WOZ value, dwelling surface, EPC, number of rooms