ERASMUS UNIVERSITY ROTTERDAM – ERASMUS SCHOOL OF ECONOMICS

Master thesis Policy Economics

Which factors inhibit householders from energy saving investments?

Author: Henk Kraijenoord (Student number: 413232)

Thesis supervisor: dr. K.F.J. Spiritus

Date final version: 11-09-2018

Abstract

To counteract the negative consequences of global warming the Dutch government encourages householders to undertake energy saving investments. Energy saving investments reduce carbon dioxide emission and yield also privately attractive returns. However, although it's privately and socially beneficial to undertake energy saving investments, the adoption of energy saving investments in the Netherlands is lower than desirable (Vringer et al., 2014). I estimate a linear probability model to determine the empirical relevance of several factors that might discourage householders to undertake energy saving investments. The results show that lack of information, principle agent problems like landlord-tenant issues and expected savings are important barriers to energy saving investments. Transaction costs don't influence the intention to invest. The existence of several barriers to energy saving investments and the need to achieve the European climate goals in 2020 imply that more stringent policy options to encourage energy saving investments are desirable.

1. Introduction

Since the beginning of the industrial revolution in the 18th century, the emission of greenhouse gases has increased rapidly. At that time, humanity began to burn fossil fuels causing an increase in carbon dioxide emission. Carbon dioxide is an important greenhouse gas which absorbs energy from the sun and bounces some of this energy back to the earth, leading to an increase in the average world temperature (Milieucentraal, 2018). The Intergovernmental Panel on Climate Change (2013) estimates that the average world temperature increased by 0.85 degrees from 1880 to 2012.

The increase in average world temperature has serious consequences for the environmental quality and impacts national and global social welfare in many ways. The increase in world temperature leads to melting glaciers and ice caps at Greenland and Antarctica and melting sea ice at the North Pole, resulting in a rising sea level. The rising sea level increases the risk on floods, which is most dramatic for densely populated areas near the coast. The increase in world temperature also increases the risk of droughts, which cause food shortage with as a consequence hunger and malnutrition. Also water scarcity will become a more severe problem, which means that drinking water becomes scarce even as water for irrigation (Milieucentraal, 2018).

However, the described global consequences of the increase in average world temperature are not for every country equally large. It's also not the case that countries who contribute the most to global warming, automatically suffer the most. For the Netherlands, the consequences of the increase in world temperature are moderate for the time being. Winters will be softer in the Netherlands and precipitation will rise in the autumn, winter and spring. Summers will be hotter and drier, with more hot summer days. Furthermore, the weather will become more extreme with more heavy rainfall and heat waves. Through the rising sea level and extreme rainfall, the risk on floods increases which means that the dikes in the Netherlands need to be strengthened (Milieucentraal, 2018).

In this paper, I consider one of the green policy instruments the Dutch government currently uses to reduce greenhouse gas emission. Through gas and electricity consumption, Dutch households were responsible for approximately 18% of the national carbon dioxide emission in 2017 (CBS, 2018). The Dutch government stimulates the adoption of energy saving investments to reduce the carbon dioxide emission in the built environment. Energy saving investments improve the energetic quality of the dwelling and reduce gas and electricity consumption. Energy saving investments include different

types of double glazing, attic, façade and floor insulation, but also energy efficient central heating boilers, solar water heaters, solar panels and other energy saving measures that improve the energetic quality of a dwelling. Energy saving investments must be distinguished from energy efficiency appliances. Energy efficiency appliances are related to energy saving investments since they're also made to reduce electricity consumption, but energy efficiency appliances do not influence the energetic quality of a dwelling. Energy efficiency appliances include refrigerators, freezers, laptops and other appliances with a high energy label. In this paper, I focus on energy saving investments, dwelling improvements that reduce energy consumption and improve the energetic quality.

In the economic literature two advantages of energy saving investments are mentioned, which are the reasons why energy saving investments are often seen as a win-win opportunity. In the first place, energy saving investments reduce energy consumption, which has positive consequences for environmental quality and hence social welfare. In the second place, energy saving investments yield attractive returns, which is beneficial for private welfare. So, energy saving investments are privately beneficial investment opportunities that have positive externality effects. However, the adoption of energy saving investments through householders depends to a large extent on the actual return on investment.

Environmental consumer organization Milieucentraal developed a standard method to calculate the private returns to energy saving investments. Based on all relevant statistics concerning the investment option, Milieucentraal calculates for every type of energy saving investment the total net benefits and the rate of return. The standard method of Milieucentraal takes into account the investment costs, maintenance costs, lifetime of the investment, average energy cost savings, the current energy price and future energy price developments. The ultimate calculated returns depend to some extent on the assumptions made and therefore Milieucentraal makes conservative assumptions, e.g. about future energy price developments. To illustrate the estimated profitability of energy saving investments, let's consider a few examples. The costs of cavity wall insulation are €800 for an average terrace house and the yearly energy cost savings €200 (Milieucentraal, 2018). The return to cavity wall insulation varies between 9%-12% depending on the assumption about the future energy price. Another example, the return to solar panels varies between 3%-5% depending on the assumption about the future energy price (Milieucentraal, 2018).

So, from trustworthy conservative calculations it's clear that the return on energy saving investments is significantly higher than the current savings interest rate. The positive

externality effect on the environmental quality could be another reason to invest in energy savings. However, despite the private and social benefits of energy saving investments, the adoption of energy saving investments in the Netherlands is lower than might be expected given the described financial attractiveness of energy saving investments. In the literature, this phenomenon is referred to as the energy paradox (Jaffe and Stavins, 1994) or the energy efficiency gap (Allcott and Greenstone, 2012; Gillingham and Palmer, 2014; Gerarden et al., 2017).

In this paper, I investigate which factors discourage householders to undertake an energy saving investment. The literature mentions several theoretical barriers to energy saving investments which can be subdivided in market failures, behavioural explanations and imperfect estimations of the returns. The literature mentions lack of (access to) information about energy saving investments, principal agent problems and transaction costs, like the time investment and mess and nuisance, as the most important barriers to energy saving investments (Hirst and Brown, 1990; Jaffe and Stavins, 1994; Scott, 1997; Gillingham and Palmer, 2014; Gerarden et al., 2017). Principal agent problems mostly arise in the form of landlord-tenant issues when the landlord has to pay the investment costs while he is not the party that pays the energy bill. Loss aversion, when the householder attaches an irrational high weight to possible negative scenarios, could be another behavioural explanation for the low uptake of energy saving investments. Finally, overestimations of the returns to energy saving investments by engineers could be a reason for the energy efficiency gap (Gillingham and Palmer, 2014; Gerarden et al., 2017).

I estimate a linear probability model to determine the empirical importance of several barriers to energy saving investments. I use data from the Dutch dwelling inspection project Woon Onderzoek Nederland 2012 (WoON 2012). The 4,709 observations are representative for the total Dutch population of 7.14 million households. The results show that lack of information, principal agent problems and expected savings are important barriers to energy saving investments. Furthermore, it turns out that house-owners are significantly more likely to have the intention to undertake an energy saving investment in the coming two years compared to renters. I do not find a significant impact of the transaction costs on the intention to invest.

The existence of several barriers to energy saving investments, like information and principle-agent problems, and the need to achieve the European climate goals in 2020 imply that more stringent policy options to encourage the adoption of energy saving investments are desirable. Interesting stringent policy options are an increase in the

energy tax or the introduction of differentiation in existing dwelling related taxes based on the energy label of the dwelling (Vringer et al., 2014). However, besides the policy implications emphasizing only the tasks and responsibilities of the government, citizens themselves are also responsible for the reduction of carbon dioxide emission in the built environment.

This paper proceeds as follows, section 2 contains a literature overview of the theoretical barriers to energy saving investments combined with empirical evidence. Section 3 gives an overview of the international environmental policy context and of the current Dutch policy to encourage energy saving investments. Section 4 describes the data source, its representativeness and gives some descriptive statistics. Section 5 presents the identification strategy and section 6 is about the results. Section 7 discusses the policy implications of the results. Finally, section 8 concludes.

2. Literature Review

Multiple studies investigated the factors that discourage people to undertake energy saving investments. The literature review is structured conform the framework the literature provides. Factors that discourage people to undertake energy saving investments can be subdivided in three categories; market failures, behavioural explanations and imprecise estimations of the returns (Gerarden et al., 2017).

2.1 Market failures

2.1.1 Lack of Information

Lack of information is often mentioned in the literature as an important factor discouraging households to undertake energy saving investments (Hirst and Brown, 1990; Scott, 1997; Gillingham and Palmer, 2014; Gerarden et al., 2017). For the decision maker, information about the costs and benefits or profitability of the investment is crucial in order to make the optimal investment decision. In case of lack of information, the decision maker doesn't have (access to) the necessary information to decide about the investment option (Gerarden et al., 2017). The information gap could be filled by third parties, offering the decision maker information about the costs and benefits of the investment option. In practice, governments try to fill the information gap by means of energy labels for energy efficient products, such as Energy Star or EnergyGuide. Furthermore, governments fund organizations that set up reliable websites with information about the profitability of energy saving investments.

Some empirical studies investigated the validity of lack of information as a barrier to energy saving investments. Allcott and Sweeney (2014) carry out a natural field experiment with a large nationwide retailer that sells water heaters. Sales agents got instructions to provide 20,000 randomly selected households information about energy cost savings and/or rebates for Energy Star models. Allcott and Sweeney (2014) conclude that the provision of information had remarkably little effect on sales of Energy Star models. The results suggest that consumers are generally disinterested in Energy Star models. Rebates of $100 on Energy Star models in combination with sales incentives, however, do increase Energy Star purchases. Allcott and Taubinsky (2015) use two complementary field experiments to find out by how much information provision affects demand for compact fluorescent lightbulbs (CFLs). CFLs last much longer and use four times less electricity than the standard incandescent light bulbs. In the first experiment, 'an artefactual field experiment', consumers choose on an online platform between CFLs and incandescent light bulbs at different relative prices. After the randomly assigned information treatment consumers had to choose again between CFLs and incandescent light bulbs. The results of the first experiment show that randomized information increases CFL market share at market prices by 12 percentage points and increases willingness to pay by $2.30. In a second natural field experiment complementary to the first experiment, subsidies and information provision were randomly assigned across shoppers at a large home improvement retailer. The results of the second experiment show that randomly assigned information provision insignificantly increased CFL market share by 5 percentage points. The authors explain the difference between the results of the two experiments by the difference in consumer populations, choice environment and treatment. After all, Allcott and Taubinsky (2015) conclude that, even after being powerfully informed, large shares of consumers prefer incandescent light bulbs, suggesting that information provision doesn't significantly affect energy efficiency purchases. Newell and Siikimäki (2014) evaluate the effect of information labels on energy efficiency purchases. The authors use a choice experiment which implies that the results are based on stated preferences of respondents. Newell and Siikimäki (2014) find that information on energy cost savings leads to more cost-efficient investments. Information about physical energy use and carbon dioxide emission did also affect energy efficiency purchases, but were less important.

So, empirical studies draw different conclusions regarding their evaluation of the theoretical argument that lack of information could prevent households from undertaking energy saving investments. However, it must be kept in mind that Allcott and Sweeney

(2014) and Allcott and Taubinsky (2015) draw their conclusions based on randomized experiments instead of stated preferences (Newell and Siikimäki, 2014). Attaching a higher value to conclusions based on randomized experiments would lead to the conclusion that lack of information might not be a major barrier for energy saving investments.

2.1.2 Principal-Agent Problems

Principal-agent problems might be another stand in the way for the adoption of energy saving investments (Jaffe and Stavins, 1994; Scott, 1997; Gillingham and Palmer, 2014; Gerarden et al., 2017). Principal-agent problems arise when the party that pays the investment costs is not the party that pays the energy bill. In that case, the investor cannot recover the investment from the energy cost savings, preventing the investor from undertaking energy saving investments. In the context of energy savings the typical example of a principal-agent problem is the landlord-tenant issue. The landlord is responsible for paying the investment cost, but the tenant enjoys the benefits in the form of energy cost savings. Another example of a principal-agent problem is the situation when relocation plans in the near future prevent a potential investor from investing.

Scott (1997) conducts empirical research to investigate whether the appropriability of the rent significantly influences the investment decision. The author regresses ownership of attic insulation, hot water cylinder insulation and low energy light bulbs on independent variables indicating whether the respondent is home-owner or rents from a landlord or local authority. Scott (1997) finds that appropriability of the rent matters for ownership of insulation. Also Davis (2011) attempts to determine empirically the importance of the landlord-tenant problem. The author compares ownership of energy efficiency appliances between home-owners and renters, controlling for household income, demographics, energy prices, weather and more. Davis (2011) finds that renters are significantly less likely to possess energy efficient refrigerators, clothes washers and dishwashers. Energy saving investments are beyond the scope of his research, but the author suggests that the landlord-tenant problem might be even worse for energy saving investments. Gillingham et al. (2012) investigate whether home-owners are significantly more likely to possess attic, ceiling or exterior wall insulation. The authors find that owner-occupied dwellings are 20 percent more likely to have attic and ceiling insulation and 13 percent more likely to have exterior wall insulation. All in all, empirical research confirms economic theory which states that principal-agent problems are a barrier to energy saving investments.

2.1.3 Hidden costs

The concept hidden costs includes both transaction costs and opportunity costs which might inhibit home-owners to invest in energy savings (Scott, 1997; Gillingham and Palmer, 2014; Gerarden et al., 2017). Transaction costs can be thought of as the required time and effort the home-owner has to put in to find out which energy saving measure to choose, workers to hire and subsidies are available. Furthermore, the installation of energy saving measures causes mess and nuisance for the occupants for a certain time period. Also opportunity costs play a role in the energy saving investment decision. Since home-owners can spend their money once, investing in energy savings also means less opportunity to invest in other profitable projects. Hidden costs are often difficult to quantify, which makes it also difficult to include hidden costs in a cost-benefit analysis.

Caird et al. (2008) conduct an online survey among adopters and non-adopters of energy saving measures. For the installation of 250mm thick attic insulation, 33% and 22% of the 59 respondents mentioned the hassle of clearing stored items from the attic space and disruption in home, respectively, as the main reason for non-adoption. The authors warn that the results might not be representative for the population at large, since the respondents were mostly 'green consumers', people who are environmentally concerned. Nevertheless, the results emphasize the importance of hidden costs in the investment decision. Also Fowlie et al. (2015) find evidence for high non-monetary cost of energy efficiency investments. The authors conducted a randomized controlled trial in which the treatment group was strongly encouraged to take up an energy efficiency retrofit. The energy efficiency retrofit out of pocket costs were zero and the improvements to the home roughly $5,000. Compared to the control group, take-up was considerably low leading Fowlie et al. (2015) to the conclusion that non-monetary costs are high. The conclusion is at least valid for the population Fowlie et al. (2015) studied, namely low income groups in the U.S.

2.1.4 Credit constraints

As long as potential energy cost savings are high enough to recover the investment costs, the upfront payment shouldn't inhibit home-owners to invest. However, when there is limited access to capital home-owners might not have the opportunity to make the optimal investment decision (Hirst and Brown, 1990; Scott, 1997; Gillingham and Palmer, 2014; Gerarden et al., 2017). This could be the consequence of credit rationing, when lenders don't grant credit to borrowers with high potential returns to energy saving investments. It might be impossible for lenders to distinguish between borrowers with high and low risk

of default and to separate borrowers with high and low potential returns to energy saving investments.

To the best of my knowledge, no study yet determined empirically the importance of credit constraints as a barrier for energy saving investments. However, at least for the Netherlands the theoretical argument is irrelevant. The national energy saving fund lends home-owners up to €25,000 for energy saving measures (Nationaal Energiebespaarfonds, 2018). The national energy saving fund grants the credit independent of the profitability of the energy saving measure (Energiebespaarlening, 2018). So, in the Dutch context, credit constraints will not inhibit home-owners to undertake energy saving investments, because the conditions for credit loans are not stringent.

2.2 Behavioural explanations

2.2.1 Learning by using spillovers

In most cases people learn about the advantages and disadvantages of a certain product by using it. Other consumers will learn from the behaviour of the early consumers. The information spillover from early consumers might be a reason for large shares of other consumers to delay the purchase. Information spillovers could also be relevant in the context of energy saving investments, home-owners might delay the investment until they learn about the advantages from early consumers (Gillingham and Palmer, 2014; Gerarden et al., 2017).

Empirical evidence concerning the existence of information spillovers in the energy efficiency context is scarce. In an empirical evaluation of several environmental policy alternatives on the diffusion of new technology, Jaffe and Stavins (1995) compare the effects of energy prices, insulation cost and building codes on the diffusion of thermal insulation in new home construction. The authors find no evidence for knowledge externalities, the empirical results suggest that the adoption of higher insulation levels of a certain builder is not influencing the insulation investment decision of other builders through information spillovers.

2.2.2 Inattention

In the decision whether or not to purchase a certain product, consumers focus only on parts of the available information and ignore other information. Inattentive consumers are misoptimizing consumers. Although the misoptimizing consumers might be wellinformed, they undervalue certain parts of the available information which results in an irrational decision (Allcott and Greenstone, 2012; Gillingham and Palmer, 2014).

Inattention can also be explained as consumers being inattentive to non-salient costs (Gerarden et al., 2017). Inattentive consumers value the purchase price more than the ancillary costs. For example, Hall (1997) finds that consumers give most attention to the purchase price of a printer and undervalue replacement ink prices which represent the largest share of total costs. The argument of inattention could also to be relevant in the energy efficiency context when home-owners undervalue energy cost savings and overvalue the investment cost.

Allcott and Wozny (2014) show empirically how consumers trade-off future energy cost savings for the purchase price of automobiles. The null hypothesis the authors test is that consumers are willing to pay $1.00 more to purchase a vehicle with $1.00 less in total discounted forecasted future fuel costs. Allcott and Wozny (2014) find that consumers are willing to pay only $0.76 in purchase price to reduce future discounted gasoline costs by $1.00. The authors conclude that consumers significantly overvalue the purchase price of automobiles, although the result is not completely robust. Allcott (2011) draws a similar conclusion from the Vehicle Ownership and Alternatives Survey. The results from the 2100-people national representative survey reveal that American consumers do not pay very much attention to fuel costs when they purchase a car. All in all, there is clear empirical evidence for inattention in the energy efficiency context, although empirical evidence is absent for energy saving investments.

2.2.3 Reference dependent preferences and loss aversion

In case of referent dependent preferences, consumers' ultimate utility depends on the distance between the outcome and their reference point. The classical example of reference dependent preferences is loss aversion (Tversky and Kahneman, 1991). In case of loss aversion, gains or losses in utility depend on the status quo, or the current situation, which functions as a reference point. A change that makes things worse, evaluated based on the neutral reference point, leads to a larger decrease in utility than the increase in utility in case of an equal gain. Stated differently, it's better not to lose €5 than to find €5. Reference dependent preferences and loss aversion could also be a barrier to energy saving investments (Gillingham and Palmer, 2014; Gerarden et al., 2017). At the time of the investment decision, the homeowner is uncertain about future energy prices and actual energy cost savings. When the home-owner attaches an irrational high weight to the potential negative scenarios, this might inhibit the home-owner from undertaking an energy saving investment with a net positive value. However, research determining the

empirical relevance of reference dependent preferences as a barrier to energy saving investments is lacking.

2.3 Imprecise estimations of the returns

2.3.1 Heterogeneity of the population

Heterogeneity of the population is one explanation why estimated returns to energy saving investments could be imprecise. The estimated return to a certain energy saving investment can be profitable on average, however, this doesn't mean that the investment is profitable for the entire population, see Figure 2.

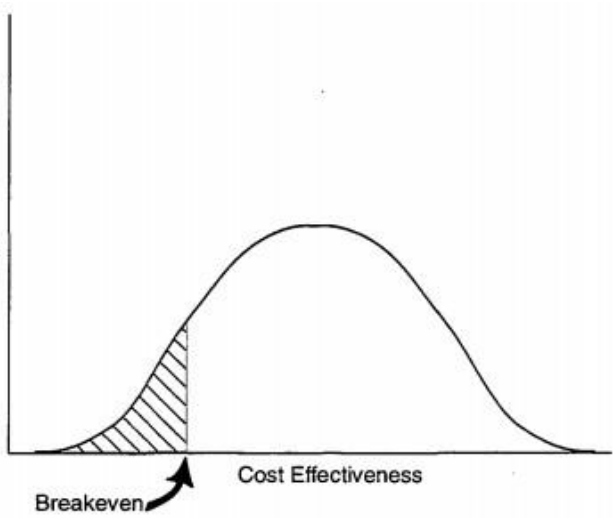

Figure 2: Heterogeneity of the population. Source: Golove (1996).

Lower than average energy consumption implies lower potential energy savings which might inhibit consumers from undertaking a seemingly profitable energy saving investment (Jaffe and Stavins, 1994; Golove, 1996; Scott, 1997; Gillingham and Palmer, 2014; Gerarden et al., 2017).

Bento et al. (2012) provide empirical evidence on the importance of consumer heterogeneity in the automobile market. Many studies investigate how consumers tradeoff future fuel costs for the purchase price of automobiles by estimating how much consumers are willing to pay more to purchase a car with $1.00 less discounted forecasted future fuel costs. Bento et al. (2012) show with a Monte Carlo analysis that the estimated MWTP will be biased towards zero when there is not sufficiently accounted for consumer heterogeneity. The results of Bento et al. (2012) imply that ignoring consumer

heterogeneity in estimating the returns to energy saving investments lead to an upward bias of the estimated return.

2.3.2 Overestimating of returns by engineers

Overestimated returns to energy saving investments by engineers could also explain why home-owners do not invest in energy efficiency (Gillingham and Palmer, 2014; Gerarden et al., 2017). One reason for an upward bias in the engineering calculations could be the assumption of perfect installation and maintenance. Wrong assumptions about expected energy use and insufficiently accounting for behavioural responses of home-owners concerning attempts to conserve energy could be other reasons for biased calculations of engineers.

Metcalf and Hassett (1999) provide empirical evidence concerning overestimated returns to energy saving investments by engineers. The authors estimate the median rate of return to attic insulation to be 9.7%. This is substantially below engineering calculations in which returns were estimated to be 50% or higher. Fowlie et al. (2018) conduct a randomized controlled trial to identify the returns to energy saving investments. The investments included in the analysis are furnace replacement, attic and wall insulation and infiltration reduction. A quarter of the 30,000 eligible participants in the Weatherization Assistance Program were randomly encouraged to participate. Encouragement increased participation in the treatment group to 6% compared to 1% in the control group. Fowlie et al. (2018) find that energy savings investments reduce monthly energy consumption by 10-20% on average. The actual energy savings were 2.5 times smaller than the model-projected savings. The disappointing actual energy savings estimated by Fowlie et al. (2018) has also consequences for the profitability of energy savings investments. Fowlie et al. (2018) estimate the private internal rate of return to energy saving investments at -2.2%. Although this estimate is not applicable to other energy saving investments (Gerarden et al., 2017), a negative pay-off would be the most important barrier to energy saving investments.

Table 1 shows an overview of the theoretical barriers to energy saving investments and their empirical relevance. Landlord-tenant problems, transaction costs, inattention, heterogeneity of the population and overestimated returns by engineers turned out to be the most important barriers to energy saving investments. Information, credit constraints and learning by using spillovers are less important and empirical evidence concerning reference dependent preferences in the energy efficiency context is lacking.

Barrier to energy efficiency investments	Empirical evidence
Market failures	
▪ **Information**	Not a major barrier
▪ **Principle-agent problems**	Barrier for energy saving investments
▪ **Transaction costs**	Barrier for energy saving investments
▪ **Credit constraints**	No barrier for energy saving investments
Behavioural explanations	
▪ **Learning by using spillovers**	Not a major barrier, but evidence is scarce
▪ **Inattention**	Barrier for energy saving investments
▪ **Reference dependent preferences**	Absent
Imprecise estimations of returns	
▪ **Heterogeneity of the population**	Barrier for energy saving investments
▪ **Overestimated returns by engineers**	Barrier for energy saving investments

Table 1: Overview of the theoretical barriers to energy saving investments and their empirical relevance.

3. Environmental policy context

Since several decades policy makers are more and more concerned about the environmental quality, because of global and national consequences of an increasing average world temperature. Since both the atmosphere and biological diversity are global public goods, international collaboration is required to reduce carbon dioxide emission. I give an overview of the international agreements to reduce greenhouse gas emissions which is to a large extent based on the facts described by Perman et al. (2003) in their textbook 'National Resource and Environmental Economics'. The described international treaties are the basis for all national environmental legislation. The Dutch green policies aimed to reduce energy consumption in the built environment, such as the policy interventions to stimulate energy saving investments are built on the goals prescribed in the international treaties.

International environmental policy context

The Toronto Conference 1988 was the first attempt to discuss international carbon dioxide emission targets. The recommended goal at the conference was a 20% reduction in carbon dioxide emission from 1988 levels. Furthermore, the Intergovernmental Panel on Climate Change (IPCC) was established at the conference. The goal of the IPCC is to review the literature to get clear what is known about (the consequences of) climate change. In 1992,

Rio de Janeiro, 150 countries signed the Framework Convention on Climate Change (FCCC). Although the 150 signatures were important and necessary, just 150 signatures was not enough. The FCCC didn't include specific carbon dioxide emission targets and there was no binding time lapse specified within which the signatories should take action.

The Kyoto Protocol 1997 was the first international agreement that contained greenhouse gas emission targets as well as a binding time limit. For all developed countries together, greenhouse gas emissions should be reduced by 5% from 1990 levels by 2008-2012. Country specific emission targets were introduced to reach the common goal. Several so called flexible mechanisms should ensure that reducing greenhouse gas emission takes place in the countries with the lowest abatement costs. Firstly, 'Emissions trading' allowed countries with high abatement costs to buy pollution credits from countries with low abatement costs. The problem, however, of 'Emissions trading' is that because of imprecisely determined targets for some countries, rich countries could buy cheap pollution credits without any additional abatement taking place in the other country. Secondly, the banking principle ensures that emission targets don't have to be met every year, but over the period 2008-2012. This offers countries more flexibility in implementing abatement programs. Finally, countries could earn emission reduction units when they would implement projects that reduce net emissions in another country, provided that the other country agrees. When the abatement costs are lower in the other country, the project improves cost effectiveness.

After the Kyoto protocol 1997 came into force, multiple conventions under the auspices of the United Nations led to the extension of the Kyoto Protocol until 2020. In 2020, greenhouse gas emissions should be reduced by 20% from 1990 levels. After 2020, the Paris agreement starts, which aims to keep the increase in average world temperature between 1.5°C - 2°C above pre-industrial revolution levels. The greenhouse gas emission levels and time limits prescribed in international agreements are binding for national governments, enforcing them to implement green policies in order to achieve the climate goals.

Dutch environmental policy context

The Dutch policy environment is characterized by several important green policies aimed to reduce energy consumption in the built environment, based on the goals prescribed in the extended Kyoto protocol and the Paris agreement. The overview of the key policies introduced to reduce energy consumption is based on the framework of Murphy et al. (2012).

1. Energy Performance Certificate

The Energy Performance Certificate (EPC) was introduced in 2008 in the Netherlands because of European legislation. The EPC is required at the moment of buying or renting a house and the energy label, ranging from A-G, provides the consumer information about the energetic quality of the dwelling. Besides the energy label, the EPC also informs the home-owner about the potential applicable energy saving investments. Currently all 5 million home-owners received an EPC from the government (Rijksoverheid, 2018). The goal of the EPC is twofold. In the first place, the EPC should stimulate market demand for energy efficient dwellings. In the second place, the EPC provides information about the potential applicable energy saving investments and this information should stimulate the home-owner to undertake an energy saving investment. Brounen and Kok (2011) conclude that consumers are willing to pay a significant premium for energy efficient dwellings. Empirical evidence concerning the second goal of the EPC is scarce, suggesting that the EPC doesn't stimulate energy saving investments (Murphy et al., 2012).

2. Subsidies, loans and fiscal instruments

Instrument	For which measure	Amount
Subsidy Sustainable Heat	Heat pump, solar water heater, pellet stove and biomass boilers.	€ 500 – € 3,400, depending on the energy saving measure.
Energy Savings Loan	All existing energy saving measures.	€ 2,500 – € 25,000.
Expansion of maximum mortgage value	All existing energy saving measures.	6% of the maximum mortgage value.
VAT Refund Solar panels	Solar Panels	21%
VAT Rebate Insulation	Dwelling insulation	6% instead of 21% VAT

Table 2: Overview of subsidies, loans and fiscal instruments targeted to stimulate energy saving investments. Source: Milieucentraal (2018) and Rijksoverheid (2018).

Table 2 shows an overview of subsidies, loans and fiscal instruments used by the government to stimulate home-owners to undertake energy saving investments. The main economic thought behind the expansion of access to credit is to reduce the financial barriers to energy saving investments for low-income groups and starters on the housing market. The additional advantage of the expansion of the maximum mortgage value is that it lowers the barrier to implement energy saving investments at the moment of relocation. Subsidies and VAT advantages also incentivize the home-owner to undertake the energy saving investment now, when the subsidy and fiscal advantages are available.

There is no recent empirical evidence available that evaluates the effectiveness of the current energy savings subsidies and VAT advantages. Murphy et al. (2012) mention from individual responses to interviews that the start-stop nature of energy subsidies hinders the effectiveness. Home-owners can never be sure about the available subsidies, once the budget is reached the subsidy is no longer available. Concerning loans, Hamilton (2010) tends to be critical towards the expansion of access to credit with the suggestion that the low take-up may be due to the small benefits, a reduction of only 1% compared to the market rate.

3. Information tools

The government has several distinct information tools at disposal to influence the investment decision of home-owners. In 2016 a campaign website was introduced to motivate home-owners to undertake an energy saving investment. The website contains stories of home-owners who already invested in energy savings and potential investors can find information about available energy saving measures (Rijksoverheid, 2018). Also the environmental consumer organization Milieucentraal provides home-owners all necessary information about energy saving investments and answers possible questions. Personal tailored advice about potential profitable energy saving investments by an independent adviser costs approximately €200 – €300 (Milieucentraal, 2018). The economic theory behind the use of information tools is to reduce unawareness of home-owners concerning the potential economic benefits of energy saving investments. Once home-owners know how to reduce energy costs, they might decide to undertake an energy saving investment. Murphy et al. (2012) conclude based on interview data that the role of information in the decision process is supportive and performed well in the Netherlands.

4. Data

I use data from the Dutch dwelling inspection project Woon Onderzoek Nederland 2012 (WoON 2012) module Energy. In commission of the Ministry of Internal Affairs and in cooperation with the Central Bureau of Statistics Netherlands (CBS), WoON 2012 is set up in order to gather statistical data about the Dutch housing market. The module Energy is an additional module to WoON 2012. Participants from WoON 2012 were asked whether they would like to participate in additional modules of WoON 2012. Participants should be at least 18 years old, live in the Netherlands and be enrolled in the basic administration of the municipality (ABF research, 2013).

WoON 2012 module Energy is developed to investigate the energetic quality of the Dutch housing stock and the influence of the behaviour of occupants on total energy consumption. The dataset consists of two parts; (i) survey data and (ii) dwelling inspection data.

i. The survey contains questions about general characteristics of the household, energy saving behaviour, the intention to undertake energy saving investments and the intention to invest in dwelling maintenance. In total, the survey contained 85 questions and it took the respondent 20-45 minutes to answer the questions.
ii. Dwelling inspectors gathered detailed information about the state of the dwelling of the respondent. The dwelling inspection data gives insight in the energetic quality and state of maintenance of the dwelling. The inspection visits lasted between 45 - 120 minutes.

Both the survey data and the dwelling inspection data were controlled by way of direct response controls. The direct response controls guarantee completeness and credibility of the survey and dwelling inspection data. The direct response controls made it impossible for the respondent and the dwelling inspector to skip questions or to give unreasonable answers (Inspectrum, 2013).

Description of the variables

In this subsection, I describe the content of the (constructed) variables of interest which I use to determine the empirical importance of several barriers to energy saving investments. Furthermore, I describe the content of some control variables and explain how I constructed them.

1. Variables of interest

I use the following variables of interest, expected savings, information, effort, costs and owner-occupied house, to determine the empirical importance of several barriers to energy saving investments. The variable owner-occupied house indicates whether the respondent owns or rents the house. Expected savings measures the degree to which the respondent believes that energy saving investments will yield attractive returns in his situation. Information measures whether the respondent knows where to find general and situation specific information about energy saving investments. The variable effort indicates to which degree the respondent is discouraged by the mess and nuisance and by the time investment he has to make to find information, subsidies and skilled labourers in order to install the energy saving investment. The variable costs measures to which degree the

investment costs discourage the respondent to undertake an energy saving investments. I combined multiple similar statements to construct the variables expected savings, information and effort. The complete overview of the original questions of (the constituents of) the variables can be found in the Appendix Table A1. The numerical values of the variables are between 1 and 5. I reversed the values of the variables expected savings, effort and costs to simplify the interpretation of the variables, resulting in the following scales. For the variable information, 'I strongly disagree' is represented by a numerical value of 1 and 'I strongly agree' by a numerical value of 5. For the variable expected savings 'I strongly disagree' is represented by a numerical value of 5 and 'I strongly agree' by a numerical value of 1. For the variables effort and costs, a numerical value of 1 stands for 'doesn't discourage me' and a numerical value of 5 for 'discourages me'. Finally, for multiple statements in the survey, I replaced 'I don't know' and 'not applicable' with numerical values 6 or 99 by a missing value.

2. *Control variables*

I generated the variable equivalised income, which is the disposable income of the household adjusted for economies of scale conform the OECD modified equivalence scale (OECD, 2018). The OECD modified equivalence scale assigns a value of 1 to the household head, of 0.5 to an additional adult and of 0.3 to each child. I generated the variable environmentalism, which indicates whether the respondent is concerned about the environment. The variable environmentalism indicates whether saving the environment is one of the key reasons for the respondent to undertake the intended energy saving investment in the coming two years. I use the variable energy conservation as a measure for the importance of energy conservation in the respondent´s daily life. The variable energy conservation indicates whether the respondent consciously tries to reduce gas and electricity consumption. Finally, I generated the variable subsidy decisive to measure the importance of the available subsidy for the intended investment. The variable subsidy decisive indicates whether the respondent either will not undertake the intended energy saving investment without an available subsidy or cannot afford the investment without subsidy.

Representativeness of the sample

From the basic module WoON 2012, 22,000 households were available for participation in additional modules like WoON 2012 module Energy. The households were subdivided in 30 strata based on their type of dwelling. For every stratum a desired percentage response

was determined to obtain a representative sample for the total Dutch population. In total, 13,240 households were approached and ultimately for 4,790 households the survey and dwelling inspection were completed. The total percentage response is 36%. The percentage response was somewhat lower for income groups below modal income, two age groups until 44 years old and non-western immigrants. The percentage response was higher for the two oldest age groups of 66 years old and older. ABF research (2013) developed a weight variable to get rid of under- and overrepresentation of certain groups. Due to the weight variable, the sample is representative for the total Dutch population of 7.14 million households.

Descriptive statistics

Table 3 shows the descriptive statistics of the sample. Approximately 16.8% of the sample, 804 of the 4,790 respondents, has the intention to undertake an energy saving investment in the coming two years. The intended energy saving investment might be exterior wall insulation, attic insulation, different types of double glazing, furnace replacement, solar panels, infiltration reduction or a combination of investments. The mean of expected savings shows that respondents react somewhat negative on the statement that energy saving investments will be effective in their situation, reflecting a somewhat negative opinion towards the expected profitability of energy saving investments in their situation. On average, the respondents state that the costs of an energy saving investment do not directly discourage them to undertake the investment. 58.1% of the respondents lives in an owner-occupied house.

The average respondent is 55 years old and the average household disposable income is approximately €35,000. The average household disposable income corrected for economies of scale conform the OECD modified equivalence scale is €23,413. A quarter of the respondents is willing to move, although it is unknown within which time period the respondent has the intention to move. The average dwelling is built in 1967. The energy index is the most important measure for the energetic quality of the dwelling. In determining the energy index, the inspector takes 150 dwelling characteristics into account, among which insulation quality etc. The energy label of the dwelling is also determined based on the energy index (RVO, 2018). An average energy index of 1.81 means that the average energetic quality of the dwellings is exactly on the border between energy label C and D. 189 respondents mention that the available subsidy is decisive in the decision to undertake the energy saving investment. In total 1,657 respondents undertook an energy saving investment in the past five years for an average amount of €2,145.

	(1) N	(2) Mean	(3) St. dev	(4) Min	(5) Max
Dependent variable					
Intention to invest (%)	4,790	0.168	0.374	0	1
Variables of interest					
Expected savings (S_1)	4,338	3.286	0.905	1	5
Information (S_2)	3,808	3.262	0.856	1	5
Effort (S_3)	4,780	3.027	0.753	1	5
Costs (S_3)	4,785	2.673	1.009	1	5
Owner-occupied house (%)	4,790	0.581	0.493	0	1
Control variables					
Age	4,790	55.51	15.76	19	93
Income (€)	4,790	34,962	20,057	-108,182	219,916
Equivalised income (€)	4,790	23,413	11,516	-51,515	158,744
Secondary education (%)	4,749	0.585	0.493	0	1
Tertiary education (%)	4,749	0.356	0.479	0	1
Energy conservation (%)	4,790	0.632	0.482	0	1
Environmentalism (%)	4,790	0.0739	0.262	0	1
Relocation plans (%)	4,790	0.237	0.425	0	1
Year of construction	4,790	1,967	30.53	1,800	2,012
Energy index	4,790	1.861	0.641	0.610	4.540
Subsidy decisive (%)	4,754	0.0398	0.195	0	1
Total energy saving investment past 5 years (€)	4,205	845.4	3,279	0	99,999
Constituents of variables of interest					
Expected savings 1 (S_1)	4,476	3.275	1.082	1	5
Expected savings 2 (S_1)	4,516	3.267	1.071	1	5
Information 1 (S_2)	4,100	3.265	0.989	1	5
Information 2 (S_2)	4,111	3.305	0.991	1	5
Information 3 (S_2)	4,115	3.278	0.998	1	5
Effort 1 (S_3)	4,785	3.176	0.970	1	5
Effort 2 (S_3)	4,786	3.051	0.987	1	5
Effort 3 (S_3)	4,786	3.183	0.997	1	5
Effort 4 (S_3)	4,781	2.681	1.024	1	5
Effort 5 (S_3)	4,785	3.045	0.976	1	5

Table 3: Descriptive statistics. Scale 1 (S_1): 1 = I strongly agree | 5 = I strongly disagree. Scale 2 (S_2): 1 = I strongly disagree | 5 = I strongly agree. Scale 3: (S_3): 1 = Doesn't discourage me | 5 = Discourages me. The complete overview of the content of (the constituents of) the variables can be found in the Appendix Table A1, which also includes the original survey questions.

5. Empirical Strategy

To investigate the factors which have a negative impact on the intention to undertake energy saving investments, I estimate the following linear probability model. Besides the factors mentioned in the formula below, I include a sample weight variable to get rid of over- and underrepresentation of certain groups.

$$Intention\ to\ invest_i = \beta_0 + \beta_1 * Expected\ savings_i + \beta_2 * Information_i + \beta_3 * Effort_i + \beta_4 * Costs_i + \beta_5 * Owner - occupied\ house_i + \beta_6 * Personal\ factors_i + \beta_7 * Dwelling\ related\ factors_i + \beta_8 * Policy\ factors_i + \varepsilon_i$$

Variables of interest

The theoretical and empirical literature shows the importance of several barriers to energy saving investments. In the model, I investigate whether there is a relationship between the intention to undertake an energy saving investment in the coming two years and several market failures and behavioural explanations that might inhibit the individual from an energy efficient investment. Coefficient β_1 measures the importance of the expected energy cost savings in explaining the intention to invest in energy savings. When the respondent has good reasons to expect lower than average energy cost savings in his situation, the return to the investment might turn out to be low or even unprofitable. In the literature this phenomenon is mentioned as heterogeneity of the population (Jaffe and Stavins, 1994; Golove, 1996; Scott, 1997; Gillingham and Palmer, 2014; Gerarden et al., 2017).

Coefficient β_2 measures the importance of lack of (access to) information. If the respondent doesn't know where to find general information or information about energy saving investments for his situation, this might explain the intention to invest of the respondent (Hirst and Brown, 1990; Scott, 1997; Gillingham and Palmer, 2014; Gerarden et al., 2017). Coefficient β_3 measures whether transaction costs influence the intention to invest. Multiple studies find that hidden costs like the time investment and also mess and nuisance might inhibit the investor from undertaking an energy saving investment.

Coefficient β_4 measures whether the investment costs function as a barrier to energy saving investments. For some investments the investment costs might be high, however, when these high investment costs can be recovered from the energy cost savings it seems irrational to reject the investment option for this reason. It should not be only costs that matter, but costs and benefits together. On the other hand, it seems reasonable that high

investment costs deter householders from investing, since there is no 100% guarantee that the investment will be profitable in the end. Finally, coefficient β_5 measures the importance of principle-agent problems. Several studies find that the landlord-tenant problem is an important explanation of the intention to invest in energy efficiency (Jaffe and Stavins, 1994; Scott, 1997; Gillingham and Palmer, 2014; Gerarden et al., 2017).

Control variables

In order to determine the empirical importance of several market failures and behavioural explanations that might inhibit the investor from undertaking an energy saving investment, I control for other factors that could explain the intention to invest. Other factors mentioned in the literature that could affect the intention to undertake an energy saving investment can be subdivided in three categories. In the first place, personal factors might explain the intention to invest in energy savings. Also dwelling related factors might play a role in the investment decision. Finally, policy factors might make householders decide to undertake an energy saving investment.

1. Personal factors

The age of the respondent can be very influential in the investment decision. For older people the investment is expected to be less profitable, because older people expect to live shorter and therefore total expected energy cost savings are lower. Ameli and Brandt (2015) confirm the empirical importance of age for the investment decision, although its effect depends on the type of investment. Ameli and Brandt (2015) find a negative relationship between age and the installation of a heat pump, whereas they find a positive relationship between age and the adoption of thermal insulation and energy efficient windows. The income level of the householder might also be influential. Rich people are more likely to undertake the investment since they can pay the investment from their savings and hence don´t have to pay interest. Long (1993) and Ameli and Brandt (2015) both find a positive relationship between income and energy saving investments.

Higher educated people might be better informed about the benefits of energy saving investments and therefore the education level might affect the investment decision. Nair et al. (2010) confirm the importance of education, although Ameli and Brandt (2015) do not consider education as a key explanatory variable for technology adoption. Both Nair et al. (2010) and Ameli and Brandt find that energy conservation practices are an important determinant of energy saving investments. Home-owners who attach a high value to energy conservation turn out to be more likely to invest.

Also environmentalism might be of particular importance for the investment decision. Ameli and Brandt (2015) find that people that are concerned about the environment are more likely to invest than non-environmentalists. People that have the intention to relocate in the near future are less likely to undertake an energy saving investment, since they cannot recover the investment cost from the energy cost savings. Finally, the number of household members is mentioned in the literature as related to the investment decision, Long (1993) finds a negative relationship, whereas Ameli and Brandt (2015) find a positive relationship. I don't think the number of household members will affect the investment decision, except through income. Therefore I control for the number of persons through equivalised income.

2. Dwelling related factors

As dwelling related factors the year of construction and the Energy Index of the dwelling may affect the intention to invest (Nair et al., 2010). For older and less energy efficient buildings it might be more profitable to invest because of higher expected energy cost savings. Furthermore, I control for the amount the respondent has invested in energy savings in the past five years. Nair et al. (2010) find that householders who already invested in energy savings in the past are also more likely to invest in the future.

3. Policy factors

Besides personal and dwelling related factors, policy factors like available subsidies might also influence the investment decision (Ameli and Brandt, 2015). I control for subsidies that might persuade householders to invest in energy savings by including a dummy variable in the model that equals 1 if the respondent mentions that he would not invested without the available subsidy.

Overview of the expected signs

Expected savings	+	Age	–	Relocation plans	–
Information	+	Equivalised income	+	Year of construction	–
Effort	–	Education	+	Energy Index	+
Costs	–	Energy conservation	+	Recent investment	+
Owner-occupied house	+	Environmentalism	+	Subsidy decisive	+

Table 4: Overview of the expected effects of the variables of interest and control variables on the intention to invest.

6. Results

Table 5 shows the main results of the linear probability model as specified in the previous section. The first column presents the results of the preferred model, the second and third column show the results of the performed robustness checks.

The first column of Table 5 shows that expected savings influences the intention to invest significantly. The positive sign on expected savings indicates that when the householder reflects a more positive opinion concerning the expected profitability of energy saving investments in his situation, he is significantly more likely to invest. It's not possible to say something about the exact size of the effect of expected savings on the intention to invest. The variable expected savings is not a continuous variable, since it's measured on a Likert scale. Therefore, the difference between 'neutral' and 'I agree' is not necessarily as large as the difference between 'I agree' and 'I strongly agree'. Despite the fact that it's not possible to determine the exact size of the effect, the significant influence of expected savings on the intention to invest in energy savings provides evidence for the existence of heterogeneous returns. Even if a certain energy saving investment is profitable for the average population, the household specific situation matters. This finding is in line with empirical evidence of Scott (1997) and Bento et al. (2012).

The availability of general and dwelling specific information about energy saving investments also has a significant influence on the intention to invest. In the survey the respondent was asked whether he knows where to find information about energy saving investments in general and information about energy saving investments adjusted to his situation. The positive sign on the variable information shows that householders who know where to find general and situation specific information about energy saving investments are significantly more likely to invest. Again, it's not possible to conclude something about the exact size of the effect of information, since information is not a continuous variable. What can be concluded is that the availability of information does influence the intention to invest significantly, but the effect is not too strong as the coefficient is borderline significant at the 5% level. This finding is in line with empirical evidence on the importance of information of Allcott and Sweeney (2014) and Allcott and Taubinsky (2015).

	(1) Intention to Invest	(2) Intention to Invest	(3) Intention to Invest
ExpectedSavings	0.022***	0.027***	0.021***
	(4.352)	(4.791)	(4.135)
Information	0.013**	0.010	0.015***
	(2.177)	(1.475)	(2.581)
Effort	-0.010	-0.003	-0.006
	(-1.331)	(-0.315)	(-0.884)
Costs	0.009*	0.002	0.009
	(1.719)	(0.371)	(1.606)
OwnerOccupiedHouse	0.108***	0.119***	0.112***
	(10.598)	(10.468)	(11.747)
Age	-0.002***	-0.002***	-0.002***
	(-5.396)	(-4.297)	(-6.365)
EquivalisedIncome	-0.000	-0.000	0.000
	(-0.370)	(-0.100)	(0.151)
SecondaryEducation	0.000	0.012	-0.006
	(0.012)	(0.711)	(-0.370)
TertiaryEducation	-0.007	0.006	-0.020
	(-0.374)	(0.283)	(-1.033)
EnergyConservation	0.020*	0.027**	0.023**
	(1.958)	(2.451)	(2.442)
Environmentalism	0.711***	0.824***	0.711***
	(44.649)	(80.332)	(48.215)
RelocationPlans	0.004	0.003	-0.003
	(0.344)	(0.253)	(-0.238)
YearOfConstruction	-0.001***	-0.001***	-0.001***
	(-2.955)	(-3.130)	(-3.071)
EneryIndex	0.003	-0.001	0.004
	(0.245)	(-0.096)	(0.405)
RecentInvestment	0.000**	0.000**	
	(2.330)	(2.097)	
SubsidyDecisive	0.451***		0.444***
	(14.124)		(14.949)
SampleWeights	-0.000	-0.000	-0.000
	(-1.517)	(-0.845)	(-0.896)
Constant	1.456***	1.567***	1.431***
	(2.897)	(3.014)	(3.012)
Observations	3,172	3,197	3,595
R-squared	0.512	0.439	0.511

*Table 5: Main results from the linear probability model. The first column presents the preferred model. The following columns represent robustness checks. Robust t-statistics in parentheses. ***p<0.01, **p<0.05, *p<0.1.*

It´s remarkable to notice that the amount of effort the householder has to put in seems not to matter for the intention to invest in energy savings in the coming two years. The amount of effort that has to be put in by the householder in the (preparations for) the installation process of the energy saving investment can also be seen as transaction costs. The

literature mentions transaction costs as one of the reasons for non-adoption of energy saving investments. In the survey the respondent was asked whether the time investment to find information, skilled labourers and an available subsidy and the mess and nuisance would discourage him to invest in energy savings. The results show that variation in the degree of discouragement concerning the transactions costs cannot explain the intention to invest.

Would this mean that transaction costs are unimportant for the energy saving investment decision? Not necessarily. Table 5 shows that before it actually comes to an investment decision, more or less discouragement by the time investment and mess and nuisance of the energy saving investment does not increase or decrease the probability that the householder will invest in energy savings significantly. The most plausible explanation for the insignificant influence of transaction costs on the intention to invest is that householders underestimate the transaction costs beforehand. The result in Table 5 differs from the evidence for the importance of transaction costs mentioned in the literature. In the literature, the dependent variable in the model is the *actual* investment decision and not the *intention* to invest in energy savings like in this paper. For example, Fowlie et al. (2015) explain the low adoption of a costless energy efficiency retrofit by high non-monetary costs. So, although transaction costs do not influence the intention to invest significantly, transaction costs might still be important for the actual investment decision. However, the importance of transaction costs for the actual investment decision is only measurable after the actual investment decision is made.

The degree of discouragement concerning the costs of an energy saving investment does also influence the intention to invest significantly. However, the coefficient on the variable costs does not have the expected sign. The positive sign on the variable costs shows that an householder which is to a lesser extent discouraged by the costs of an energy saving investment is less likely to invest. In other words, an householder which is to a larger extent discouraged by the costs of an energy saving investment is more likely to invest. The positive sign on the variable costs implies that the investment costs are not a major barrier to energy saving investments. Otherwise, householders which would be discouraged by the investment costs would be less likely to invest in energy savings. The irrelevance of the investment costs might be explained by the availability of cheap credit for energy saving investments in the Netherlands.

Whether the respondent owns or rents his house influences significantly the intention to undertake an energy saving investment in the coming two years. In contrast to the

interpretation of the previous coefficients, the interpretation of the coefficient on owner-occupied house is relatively easy. Column (1) in Table 5 shows that house-owners are 10.8% more likely to undertake an energy saving investment compared to renters. So there is strong evidence for the existence of principle agent issues like the landlord-tenant problem. When the investor cannot recover the investment from the energy cost savings, he will be significantly less likely to undertake the investment. This finding is in line with empirical evidence of Scott (1997), Davis (2011) and Gillingham et al. (2012).

The variable environmentalism points out that saving the environment is an important reason for householders to undertake an energy saving investment. The respondent who mentions saving the environment as a key explanation for the intended energy saving investment is significantly more likely to undertake an energy saving investment. Environmentalists do, besides the private benefits of energy saving investments, the energy costs savings, also take the social benefits of energy saving investments into account. This explains why environmentalists are significantly more likely to invest in energy savings than non-environmentalists. The result that environmentalists are more likely to undertake an energy saving investment is in line with empirical evidence of Ameli and Brandt (2015).

The significance of the variable subsidy decisive shows that available subsidies play an important role in the energy saving investment decision. When the respondent mentions that he would not invest in energy savings without an available subsidy influences the intention to invest significantly. The importance of subsidies in the energy saving investment decision is in line with empirical evidence of Ameli and Brandt (2015).

Income corrected for economies of scale, the education level, the intention to relocate in the near future and the energetic quality of the dwelling do not influence the intention to invest significantly. The insignificance of equivalised income and relocation plans can be explained by the availability of cheap credit and the uncertainty within which period the respondent has the intention to relocate. The significance of year of construction shows that it's not so much the energetic quality of the dwelling that drives the intention to invest, but necessary maintenance that can be executed in the form of an energy saving investment. Since the energy index does not influence the intention to invest significantly, the lower energetic quality of an old dwelling cannot be the main reason that house-owners of old houses are more likely to undertake an energy saving investment. It´s most plausible that house-owners of older houses have to execute necessary maintenance and do this in the form of an energy saving investment. The robustness check in column (3) shows that

the results remain unchanged when recent investment is excluded from the model and the number of observations increases to 3,595.

Potential threats to the internal validity

The results of the linear probability model show that the expected energy cost savings, the degree of information and whether the householder owns or rents the house matter significantly for the intention to undertake an energy saving investment in the coming two years. The amount of hidden costs, like the time investment and mess and nuisance, and the investment costs do not inhibit the householder to undertake an energy saving investment. However, in order to draw policy implications from the estimated results it's important to consider the potential threats to the internal validity of the model. A study is internally valid if its statistical inferences are valid for the population and setting studied. In this paper, the population studied are Dutch householders in a setting representative for the Dutch housing market. I discuss the relevance of the following three potential sources of endogeneity in the model, 1. Omitted variable bias, 2. Errors in variables and 3. Reverse causality.

1. Omitted variable bias

An omitted variable bias is an important threat to the internal validity. In simple linear regression models without control variables the estimated coefficient is just the difference in the dependent variable between the treatment and control group. By adding control variables to the model, the estimated effect will be cleaned from other factors that influence the dependent variable. In the context of this paper, other factors that influence the intention to undertake an energy saving investment in the coming two years must be controlled for. The control variables assure that the coefficients of the variables of interest are not over- or underestimated because of other factors that influence the intention to invest. In order to identify the relationship between factors that discourage householders to invest and the intention to undertake an energy saving investment, I control for other factors that influence the intention to invest. The model would suffer from an omitted variable bias when other factors that influence the intention to invest are not included in the model. In the model, as described in the previous section, I included all relevant determinants of energy saving investments mentioned in the literature to get rid of an omitted variable bias. However, although all relevant determinants of energy saving investments mentioned in the literature are included in the model, it's impossible to include all possible confounders in the model. Furthermore, there is still a certain chance

that there are immeasurable factors that cannot be included in the model. Because of these limitations in the identification strategy, the estimated coefficients might change when all relevant confounders would be included in the model.

2. Errors in variables

An errors in variables bias can arise in two forms, namely a measurement error in the dependent variable and a measurement error in the independent variable. Let's first discuss the case of a measurement error in the dependent variable. When the dependent variable in the model contains a random measurement error it will reduce the precision because of a larger variance. However, a random measurement error in the dependent variable won't lead to a bias. A non-random measurement error in the dependent variable will cause a downward or upward bias. In the context of this paper, a measurement error in the dependent variable might exist when people on purpose fill in the wrong answer and hence lie about the question whether they intend to undertake an energy saving investment in the coming two years. One reason to give the wrong answer might be to skip questions.

An errors in variables bias can also arise when the independent variable is measured imprecisely. A measurement error in the independent variable is also either random or non-random. A random measurement error in the independent variable biases the coefficients towards zero. A non-random measurement error in the independent variable causes an upward or downward bias. In the context of this paper, the variables of interest except owner-occupied house might be prone to a measurement error. The answers to survey questions, in some sense stated preferences, may always be different from revealed preferences. For example, people might over- or underestimate whether they are able to find the right information about energy saving investments. Or people might become imprecise just because they want to finish the survey. However, people that are most likely to cause a measurement error are also most likely to choose the 'I don't know' option. The 'I don't know' option is the most easy option for the people that are not completely sure about their answer or want to finish quickly. So, the 'I don't know option significantly reduces the chance on a measurement error. Still there is some chance that the independent variables of interest except owner-occupied house contain some measurement error, which would lead to a small underestimation of the coefficients.

3. Simultaneous causality

In a linear regression model, causality runs from the independent variable to the dependent variable, but can also run from the dependent variable to the independent variable. When there is an effect of the dependent variable on the independent variable, the estimated coefficient is biased. If the effect of the dependent variable on the independent variable is negative, then the estimated coefficient is underestimated. When the effect of the dependent variable on the independent variable is positive, then the coefficient is overestimated. In the context of this paper, the intention to invest may have an influence on the degree to which people know where to find information about energy saving investments. When people have the idea to invest in energy savings in the coming two years people will also search for information and hence know where to find information about energy saving investments. For the other variables of interest, I don´t think the intention to invest has an influence on the decision to buy or rent a house, the degree of discouragement due to transactions costs and investment costs and the expected energy cost savings.

7. Policy Implications

The significant influence of information on the intention to invest in energy savings stresses the importance of information tools as an instrument to stimulate energy saving investments. Information tools like the national campaign website and the environmental consumer organization Milieucentraal remain important in order to achieve the climate goals.

The results emphasize the importance of personal tailored advice about energy saving investments. Personal tailored advice could give householders more insight in the actual expected energy cost savings. Several policy instruments currently used in the Netherlands provide householders the opportunity to get informed about the most profitable energy saving investments. Milieucentraal and Rijksdienst voor Ondernemend Nederland (RVO) provide a website where householders can easily find which energy saving investment is most profitable for their dwelling. Furthermore, around 200 municipalities have a counter where habitants can get detailed information about energy saving investments. So, I agree with Murphy et al. (2012) that the role of the government concerning information provision is performed well in the Netherlands.

Besides the current policy instruments the government uses to stimulate energy saving investments, it might well be necessary to use more stringent policy instruments. More stringent policy instruments are in the first place necessary because of the significance of barriers to energy saving investments like the principal agent problem. In the second place, more stringent policy options are necessary to achieve the European climate goals in 2020 of 20% carbon dioxide reduction. Thirdly, Vringer et al. (2014) conclude that the current policy instruments are too weak to encourage homeowners to undertake energy saving investments.

Interesting stringent policy options are an increase in the energy tax or the introduction of differentiation in existing dwelling related taxes based on the energy label of the dwelling (Vringer et al., 2014). The mechanism behind the increase in the energy tax works in the following way. When the energy tax increases, renters will have a stronger preference for energy efficient dwellings, resulting in a higher rental price for energy efficient dwellings. This might incentivize landlords to improve the energetic quality of their dwelling. A final interesting stringent policy option to improve the energetic quality of the housing stock in the Netherlands would be to oblige householders to improve the energetic quality of their dwelling. However, such a policy measure restricts the freedom of citizens and might cause a lot of political resistance.

8. Conclusion

Many environmental changes led to the general opinion among scientists that global warming cannot be seen independent from human activity. The IPCC estimates that the average world temperature increased by 0.85°C from 1880 to 2012 as a consequence of increased carbon dioxide emission. The increase in average world temperature impacts national and global social welfare in many ways. Melting sea ice at the North Pole, rising sea levels, droughts, food shortage and water scarcity are the most important threats to social welfare (Milieucentraal, 2018). International collaboration and awareness is an important first step to counteract the consequences of climate change, however, because of national sovereignty national initiatives are going to be decisive.

In this paper, I discuss an important national initiative to reduce carbon dioxide emission, namely stimulating energy saving investments. Energy saving investments yield high private returns and improve environmental quality, which is considered a win-win situation. For example, Metcalf and Hassett (1999) estimate a 9.7% return to attic insulation. However, although energy saving investments seem an attractive profitable

opportunity to increase utility, the willingness to invest of home-owners is low. This phenomenon is what Jaffe and Stavins (1994) call the energy paradox or the energy efficiency gap.

In order to explain the energy efficiency gap, the literature mentions several barriers to energy saving investments, which can be subdivided in market failures, behavioural explanations and imprecise estimations of the returns. In the literature, lack of information is often mentioned as an important market failure inhibiting home-owners to invest in energy efficiency (Hirst and Brown, 1990; Scott, 1997; Gillingham and Palmer, 2014; Gerarden et al., 2017). Principle agent problems might be another stand in the way for the adoption of energy saving investments (Jaffe and Stavins, 1994; Scott, 1997; Gillingham and Palmer, 2014; Gerarden et al., 2017). Principal agent problems arise when the party that has to pay the investment costs is not the party that pays the energy bill. Principal agent problems mostly arise in the form of landlord-tenant issues. Transaction costs, to be thought of as the time and effort the home-owner has to put in, but also mess and nuisance, are also mentioned as a barrier to energy saving investments (Scott, 1997; Gillingham and Palmer, 2014; Gerarden et al., 2017). A behavioural explanation that sheds light on the low take up of energy saving investments is, among others, loss aversion (Gillingham and Palmer, 2014; Gerarden et al., 2017). Home-owners might attach an irrational high weight to potential negative scenarios which might inhibit to undertake a profitable energy saving investment. Finally, overestimations of the returns to energy saving investments by engineers could be a reason for the energy efficiency gap (Gillingham and Palmer, 2014; Gerarden et al., 2017).

I use data from the Dutch dwelling inspection project WoON 2012, set up in commission of the ministry of Internal Affairs. The database contains 4,709 observations and consists of both survey and dwelling inspection data. Due to a weight variable the total sample is representative for the total Dutch population of 7.14 million households. I estimate a linear probability model to determine the importance of several barriers to energy saving investments. I regress the intention to invest in energy savings in the coming two years on expected savings, information, effort, costs and owner-occupied house, controlling for other factors that could influence the intention to invest.

The results from the linear probability model show that expected savings influences the intention to invest in energy savings significantly. The significant influence of expected savings on the intention to invest provides evidence for the existence of heterogeneous returns. The availability of general and dwelling specific information has also a significant

influence on the intention to invest. The transaction cost or the amount of effort the householder has to put in seems not to matter for the intention to invest in energy savings in the coming two years. The results show that variation in the degree of discouragement concerning the transaction costs cannot explain the intention to invest. The most plausible explanation for this finding is that householders might significantly underestimate transaction costs beforehand. Furthermore, I find that the investment costs of an energy saving investment do not influence the intention to invest negatively. This finding might be explained by the availability of cheap credit for energy saving investments in the Netherlands. Finally, whether the householder owns or rents the house also influences the intention to invest significantly. House-owners are 10.8% more likely to undertake an energy saving investment compared to renters, which is strong evidence for the existence of principal agent problems like landlord-tenant issues. The reader must be careful in interpreting the estimated coefficients, which cannot be interpreted as causal. Limitations in the identification strategy result in several threats to the internal validity of the model which must be taken into account when interpreting the results.

Key elements of the current Dutch policy aimed to reduce carbon dioxide emission in the built environment are the Energy Performance Certificate, subsidies, loans, VAT advantages and information tools. The significance of information emphasizes the importance of information tools like environmental consumer organization Milieucentraal and national campaign websites in order to stimulate energy saving investments. Most important, the existence of several barriers to energy saving investments, like information and principle-agent problems, and the need to achieve the European climate goals in 2020 imply that more stringent policy options are desirable. Interesting stringent policy options are an increase in the energy tax or the introduction of differentiation in existing dwelling related taxes based on the energy label of the dwelling (Vringer et al., 2014). However, besides the policy implications emphasizing only the tasks and responsibilities of the government, citizens themselves are also responsible for a reduction of carbon dioxide emission in the built environment.

References

ABF research. (2013). *Dataprocessing WoON Energie 2012*. Delft.

Allcott, H. (2011). Consumers' perceptions and misperceptions of energy costs. *American Economic Review*, *101*(3), 98-104.

Allcott, H., & Greenstone, M. (2012). Is there an energy efficiency gap?. *Journal of Economic Perspectives*, *26*(1), 3-28.

Allcott, H., & Sweeney, R. (2014). *Information disclosure through agents: evidence from a field experiment*. National Bureau of Economic Research.

Allcott, H., & Wozny, N. (2014). Gasoline prices, fuel economy, and the energy paradox. *Review of Economics and Statistics*, *96*(5), 779-795.

Allcott, H., & Taubinsky, D. (2015). Evaluating behaviorally motivated policy: Experimental evidence from the lightbulb market. *American Economic Review*, *105*(8), 2501-38.

Ameli, N., & Brandt, N. (2015). Determinants of households' investment in energy efficiency and renewables: evidence from the OECD survey on household environmental behaviour and attitudes. *Environmental Research Letters*, *10*(4), 044015.

Bento, A. M., Li, S., & Roth, K. (2012). Is there an energy paradox in fuel economy? A note on the role of consumer heterogeneity and sorting bias. *Economics Letters*, *115*(1), 44-48.

Brounen, D., & Kok, N. (2011). On the economics of energy labels in the housing market. *Journal of Environmental Economics and Management*, *62*(2), 166-179.

Caird, S., Roy, R., & Herring, H. (2008). Improving the energy performance of UK households: Results from surveys of consumer adoption and use of low-and zero-carbon technologies. *Energy Efficiency*, *1*(2), 149.

CBS. (2018, Juli 6). *Hogere CO2-uitstoot in het eerste kwartaal 2018*. Retrieved from CBS: https://www.cbs.nl/nl-nl/nieuws/2018/20/hogere-co2-uitstoot-in-het-eerstekwartaal-2018

Davis, L. W. (2011). Evaluating the slow adoption of energy efficient investments: are renters less likely to have energy efficient appliances?. In *The design and implementation of US climate policy* (pp. 301-316). University of Chicago Press.

Energiebespaarlening. (2018, Juli 11). Retrieved from https://www.energiebespaarlening.nl/particulieren/

Fowlie, M., Greenstone, M., & Wolfram, C. (2015). Are the non-monetary costs of energy efficiency investments large? Understanding low take-up of a free energy efficiency program. *American Economic Review*, *105*(5), 201-04.

Fowlie, M., Greenstone, M., & Wolfram, C. (2018). Do energy efficiency investments deliver? Evidence from the weatherization assistance program. *The Quarterly Journal of Economics*, *133*(3), 1597-1644.

Gerarden, T. D., Newell, R. G., & Stavins, R. N. (2017). Assessing the energy-efficiency gap. *Journal of Economic Literature*, *55*(4), 1486-1525.

Gillingham, K., Harding, M., & Rapson, D. (2012). Split incentives in residential energy consumption. *The Energy Journal*, 37-62.

Gillingham, K., & Palmer, K. (2014). Bridging the energy efficiency gap: Policy insights from economic theory and empirical evidence. *Review of Environmental Economics and Policy*, *8*(1), 18-38.

Golove, W. H. (1996). Market Barriers to Energy Efficiency: A Critical Reappraisal of the Rationale for Public Policies to Promote Energy Efficience.

Hall, R. (1997). The inkjet aftermarket: An economic analysis. *Unpublished Manuscript, Stanford University*.

Hamilton, B. (2010). A comparison of energy efficiency programmes for existing homes in eleven countries. *A report by the Regulatory Assistance Project prepared for the Department of Energy and Climate Change of the United Kingdom*.

Hirst, E., & Brown, M. (1990). Closing the efficiency gap: barriers to the efficient use of energy. *Resources, Conservation and Recycling*, *3*(4), 267-281.

Inspectrum. (2013). *Veldwerkverslag WoON 2012.*

IPCC, 2013: Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Jaffe, A. B., & Stavins, R. N. (1994). The energy-efficiency gap What does it mean?. *Energy policy*, *22*(10), 804-810.

Jaffe, A. B., & Stavins, R. N. (1995). Dynamic incentives of environmental regulations: The effects of alternative policy instruments on technology diffusion. *Journal of environmental economics and management*, *29*(3), S43-S63.

Long, J. E. (1993). An econometric analysis of residential expenditures on energy conservation and renewable energy sources. *Energy Economics*, *15*(4), 232-238.

Metcalf, G. E., & Hassett, K. A. (1999). Measuring the energy savings from home improvement investments: evidence from monthly billing data. *Review of economics and statistics*, *81*(3), 516-528.

Milieucentraal. (2018, Juli 30). *Klimaatverandering*. Retrieved from Milieucentraal: https://www.milieucentraal.nl/klimaat-en-aarde/klimaatverandering/

Milieucentraal. (2018, Juli 25). *Maatwerkadvies energiebesparing*. Retrieved from Milieucentraal: https://www.milieucentraal.nl/energie-besparen/energiezuinighuis/persoonlijk-energieadvies/maatwerkadvies-energiebesparing/

Milieucentraal. (2018, Juli 30). *Rendement energiebesparing*. Retrieved from Milieucentraal: https://www.milieucentraal.nl/energie-besparen/energiezuinighuis/financiering-energie-besparen/rendement-energiebesparing/

Milieucentraal. (2018, Juli 30). *Spouwmuurisolatie*. Retrieved from Milieucentraal: https://www.milieucentraal.nl/energie-besparen/energiezuinig-huis/isoleren-enbesparen/spouwmuurisolatie/

Milieucentraal. (2018, Juli 25). *Subsidie woningisolatie en duurzame energie*. Retrieved from Milieucentraal: https://www.milieucentraal.nl/energie-besparen/energiezuinighuis/financiering-energie-besparen/subsidie-woningisolatie-en-duurzame-energie/

Murphy, L., Meijer, F., & Visscher, H. (2012). A qualitative evaluation of policy instruments used to improve energy performance of existing private dwellings in the Netherlands. *Energy Policy*, *45*, 459-468.

Nair, G., Gustavsson, L., & Mahapatra, K. (2010). Factors influencing energy efficiency investments in existing Swedish residential buildings. *Energy Policy, 38*(6), 2956-2963.

Nationaal Energiebespaarfonds. (2018, Juli 11). Retrieved from Rijksdienst voor Ondernemend Nederland: https://www.rvo.nl/onderwerpen/innovatiefondernemen/innovatiefinanciering/toolbox-financieringsconstructies/zoek-opconstructies/fondsen/energiebespaarfonds

Newell, R. G., & Siikamäki, J. (2014). Nudging energy efficiency behavior: The role of information labels. *Journal of the Association of Environmental and Resource Economists*, *1*(4), 555-598.

OECD. (2018, Juli 17). *WHAT ARE EQUIVALENCE SCALES?* Retrieved from http://www.oecd.org/eco/growth/OECD-Note-EquivalenceScales.pdf

Rijksoverheid. (2018, Juli 25). *Energielabel woning*. Retrieved from Rijksoverheid: https://www.rijksoverheid.nl/onderwerpen/energielabel-woningen-engebouwen/energielabel-woning

Rijksoverheid. (2018, Juli 25). *Over deze campagne*. Retrieved from Energie besparen doe je nu: https://www.energiebesparendoejenu.nl/over-deze-campagne/

Rijksoverheid. (2018, Juli 25). *Subsidies en leningen*. Retrieved from Energiebesparendoejenu: https://www.energiebesparendoejenu.nl/subsidies-en-leningen/

RVO. (2018, Juli 18). *Energie-Index*. Retrieved from Rijksdienst voor Ondernemend Nederland: https://www.rvo.nl/onderwerpen/duurzaam-ondernemen/gebouwen/wettenen-regels-gebouwen/bestaande-bouw/energie-index

Scott, S. (1997). Household energy efficiency in Ireland: A replication study of ownership of energy saving items. *Energy Economics*, *19*(2), 187-208.

Tversky, A., & Kahneman, D. (1991). Loss aversion in riskless choice: A referencedependent model. *The quarterly journal of economics*, *106*(4), 1039-1061.

Vringer, Middelkoop, v., & Hoogervorst. (2014). *Energie besparen gaat niet vanzelf; Evaluatie energiebesparingsbeleid voor de gebouwde omgeving.*

Appendix

	Original question or description of the variable
Dependent variable	
Intention to invest	'Do you intend to undertake an energy saving investment in the coming two years?'
Variables of interest	
Expected savings (S_1)	Whether the respondent believes if energy saving investments will be profitable in his situation.
Information (S_2)	Whether the respondent is informed and knows where to find general and situation specific information.
Effort (S_3)	Whether the effort the respondent has to put in discourages him to undertake an energy saving investment.
Costs (S_3)	Whether the costs discourage the respondent to undertake an energy saving investment.
Owner-occupied house	Whether the respondent owns or rents the house.
Control variables	
Age	Age of the respondent.
Income	Disposable income of the household.
Equivalised income	Equivalised disposable income of the household, calculated conform the OECD modified equivalence scale.
Relocation plans	Whether the respondent has the intention to move.
Year of construction	Year of construction of the dwelling.
Energy index	Energy index of the dwelling.
Subsidy decisive	'How important is an eventually available subsidy for the decision to undertake the energy saving investment?'
Primary education	The percentage of respondents for whom primary education is the highest completed education.
Secondary education	The percentage of respondents for whom secondary education is the highest completed education.
Tertiary education	The percentage of respondents for whom tertiary education is the highest completed education.
Environmentalism	The percentage of respondents that mentions 'saving the environment' as key explanation for the intended energy saving investment.
Energy conservation	The percentage of respondent that consciously tried to reduce gas and energy consumption in the past 12 months.
Total energy saving investment past 5 years (€)	The amount of money the home-owner invested in energy savings in the past 5 years.
Constituents variables of interest	
Expected savings 1 (S_1)	'In my house, energy saving measures will not be effective.'

Expected savings 2 (S_1)	'I believe that energy saving measures will not have a significant impact on my energy costs.'
Information 1 (S_2)	'I know what's needed when I want to apply energy saving measures to my home.'
Information 2 (S_2)	'I know where I can find general information about energy conservation.'
Information 3 (S_2)	'I know which organizations can give me advice about energy saving investment for my house'.
	'To which extent do the following factors discourage you to undertake an energy saving investment?'
Effort 1 (S_3)	'The required time and effort to find information about energy saving investments'
Effort 2 (S_3)	'The required time and effort it costs to install the energy saving investment'
Effort 3 (S_3)	'The mess and nuisance of the installation of the energy saving investment'
Effort 4 (S_3)	'The search process to find available subsidies'
Effort 5 (S_3)	'The search process to find skilled labourers'
Costs 1 (S_3)	'The costs to undertake energy saving investments'

Table A1: Overview of the original questions or content of (the constituents of) the variables. Scale 1 (S_1): 1 = I strongly agree | 5 = I strongly disagree. Scale 2 (S_2): 1 = I strongly disagree | 5 = I strongly agree. Scale 3: (S_3): 1 = Doesn't discourage me | 5 = Discourages me.