Split Incentives and Energy Efficiency: Evidence from the Dutch Housing Market

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Abstract

Landlords and tenants have different incentives in making energy efficiency investments in housing. Landlords mostly do not pay the energy bills, but do have to make the investments. So when energy efficiency improvements are not adequately reflected in the rental market, this may lead to landlords underinvesting in energy efficiency. This is the so-called split incentive problem, but there is no consensus on whether this phenomenon is at play in the real estate market. A large panel dataset from the Dutch housing market enables us to investigate whether tenure status affects the level of energy efficiency. Using information on nearly three million homes and their residents over six years, we track the over-time change in tenure status, from a rental to an owner-occupied home. Since energy consumption is closely related to a host of dwelling and household characteristics it is crucial to adequately control for differences between homeowners and renters. The results of the most robust estimations, holding both the dwelling and household constant, show that there is no evidence for a split incentive problem in energy efficiency investments in the Dutch housing market.

Keywords: energy efficiency, split incentives, energy consumption, housing market

JEL Codes: D12, Q40, R20

1. Introduction and Background

The built environment is recognized as one of the largest consumers of natural resources and polluters of the environment. Within the European Union, buildings are responsible for 40 percent of energy consumption and 36 percent of CO2 emissions.[1] Where the residential sector in the European Union consumed more than 25 percent of final energy in 2015. For the Netherlands, this is some 20 percent.[2] Hence, the real estate sector as a whole can play an instrumental role in reaching climate goals such as set forth in the Paris Agreement, and this is receiving increasing attention from policy makers, regulators, investors and building owners.

In the residential sector various studies have looked at the relationship between the environmental performance and the financial performance of buildings, using green building certifications as a proxy for sustainability and energy efficiency. In general, these studies document that more energy efficient properties sell and rent for more than their less efficient counterparts. For commercial real estate, this has been well established by Eichholtz et al. (2010, 2013), Fuerst and McAllister (2011), and Chegut et al. (2015). For residential real estate, studies by Brounen and Kok (2011), Cerin et al. (2014), Chegut et al. (2016), Feige et al. (2013), Hyland et al. (2013), and Kahn and Kok (2013) have resulted in a clear consensus that sustainable assets have higher rents, higher transaction prices, and more liquidity in terms of time on the market.

Despite the consensus regarding the presence of a green premium for energy efficient homes in the real estate literature, investment inefficiencies in energy efficiency remain. The energy efficiency gap, described as the difference between

[1] Retrieved from: https://ec.europa.eu/energy/en/topics/energy-efficiency/buildings.
[2] Authors' calculations based on final energy consumption statistics by sector retrieved from Eurostat: http://ec.europa.eu/eurostat/tgm/refreshTableAction.do?tab=table&plugin=1&pcode=tsdpc320&language=en.

actual and optimal energy use is often hailed as an explanation for these inefficiencies. A lack of information to energy end-users is one of the reasons for the existence of the energy efficiency gap. Nonetheless, Alcott and Greenstone (2012) conclude that although some consumers are imperfectly informed and investment inefficiencies lead to an increase in energy use in multiple settings, the empirical magnitude of these inefficiencies is much smaller than often calculated in engineering analyses.

Another strand of work focuses on the split incentives between landlord and tenant, also leading to possible underinvestment in energy efficiency. Split incentives in residential energy consumption occur in rental housing between owners and tenants, and they can go to ways. First, when the tenant is not (directly) responsible for the utility bill, this may lead to over-consumption of energy. Second, when the tenant is responsible for the utility bill, this may impede building owners from making investments in the energy efficiency of their asset since they would not benefit from a lower utility bill. Most studies investigate the first split incentive problem and focus on the alleged over-consumption of energy, comparing consumption patterns of individually metered occupants that directly pay their utility bill to occupants that pay for their utilities as part of their rent.

Levinson and Niemann (2004) examine the split incentive between landlord and tenant for rental contracts that include utility costs. Their findings show that despite a higher rent for units that include utility costs in the rental contract as compared to similar metered units, the rent increment for units that include utilities is smaller than the cost of the consumed energy. The authors argue that landlords value such contracts more than the costs of the extra energy that is consumed.

Similarly, Maruejols and Young (2011) investigate how split incentives influence the behavior of tenants in Canadian multi-family housing. By using two groups of tenants the authors assess the difference in energy consumption patterns between tenants who have a rental contract that includes energy and tenants who pay their own utility bill. The results suggest that tenants who do not directly pay for their energy consumption increase their thermal comfort and are less sensitive to the dwelling being unoccupied. Moreover, these differences are more salient for older buildings. The authors conclude that their results support the existence of a split incentive problem and suggest that individual metering may have considerable effects on the energy consumption behavior of tenants.

Gillingham et al. (2012) examine the presence of split incentives in rental units in California. The authors estimate that households who pay for their own energy are 16 percent more likely to change the heating setting overnight than households who do not directly pay for their energy. However, the authors find little empirical support for differences in the temperature level across tenant types. In addition, dwellings tend to be better insulated when the owner pays for heating, alluding to a second set of split incentives. Owners who do not pay for heating may be less likely to invest in improving the insulation quality of an asset. The authors conclude that although split incentive problems have an effect on household behavior, they only have a moderate impact on energy consumption and carbon dioxide emissions. They argue that the group of households that do not pay for heating and the behavioral changes are too small to have a substantial impact on the environmental performance of buildings.

As part of the landlord-tenant problem, Davis (2011) examines appliance ownership patterns between homeowners and rental tenants using the Residential Energy Consumption Survey. The author documents that renters are significantly less likely to own energy efficient appliances. The study focuses on a set of appliances that represents about 25 percent of energy consumption in rental housing units. Heating and cooling represents the other 75 percent, for which the agency issues may actually be worse.

The second type of the split incentive hypothesis, which would predict that landlords would underinvest in the energy efficiency improvements of their real estate assets, has received less attention in the literature, but plays a leading role in policy discussions. Rehdanz (2007) assesses the determinants of space heating expenditures in the German housing market, controlling for a variety of building and household characteristics. The author documents that homeowners spend 13 percent less on space heating than rental tenants. The author suggests that this finding may allude to homeowners being more likely to invest in energy efficiency improvements than tenants.

A similar study for the U.K. by Meier and Rehdanz (2010) uses an annual panel over a fifteen-year period to explain differences in heating expenditures. In contrast to Rehdanz (2007), the authors conclude that homeownership is associated with a 3 percent increase in space heating expenditure, controlling for building and household characteristics. However, when restricting the sample to similar building types the authors do not find evidence for differences in heating expenditures for homeowners and rental tenants. As a possible explanation for these finding, the authors suggest that rental units tend to be more energy efficient in the U.K. Moreover, homeowners predominantly occupy detached or semi-detached homes, suggesting that higher levels of heat loss in such homes may explain the initial difference in heating expenditure.

Wood et al. (2012) perform a cross-sectional analysis for the residential real estate market in Australia. By extensively controlling for location, climate, dwelling, and household characteristics the authors aim to disentangle the impact of tenure on energy expenditure. The authors conclude that the average energy expenditure in Australia is some 15 percent higher for homeowners than for rental tenants. The different institutional environment in Australia is offered as a possible explanation for the divergence of the results from other studies.

Another of the few studies to analyze the second type of split incentive is Charlier (2015). The author documents that homeowners are more likely to invest in energy efficiency than rental tenants. The analysis confirms that occupancy status is an important determinant of investment in energy efficiency improvements. Moreover, the author concludes that tenants face a two-fold disadvantage relative to homeowners. First, tenants face higher energy costs due to lower building quality, and consequently lower energy efficiency. Second, they face a higher burden of these energy costs since rental tenants, on average, have a lower income than homeowners.

Taken together, the findings indicate that the effect of tenure on energy expenditure and the likelihood to invest in energy efficiency improvements differs across countries. Moreover, these studies document that building and household characteristics differ substantially among owner-occupied and tenant-occupied homes. For example, homeowners tend to have a higher income and wealth, often occupy larger and detached or semi-detached homes, and have a different household composition than rental tenants.

Therefore, it is not clear whether this presumed underinvestment does occur in reality. For example, despite the presence of split incentives, a recent study by Chegut et al. (2016) shows that residential building owners are able to recover part of their investment in energy efficiency at the time they sell their assets in the private market. This is especially the case when the investment in energy efficiency is part of a broader renovation improving the overall quality of the dwelling.

The best way to investigate whether this split incentive problem really affects the energy efficiency of dwellings is to study the energy performance of homes that experience a change in tenure status. This is where the contribution of our study lies. By examining a large number of homes transacted in the Dutch housing market, we are able to observe changes in tenure and their impact on energy consumption. We relate changes in the energy consumption pattern for the same dwelling over time to the change in tenure, controlling elaborately for household characteristics.

In addition, for a subset of homes we observe the same household acquiring the home, enabling us to hold the dwelling and household constant. By gradually increasing the robustness of our estimation procedure we document that when correctly controlling for possible endogeneity, there is no evidence for a split incentive problem in energy efficiency investments in the Dutch housing market.

2. Data

In order to investigate whether investments in the energy performance of homes in the Dutch residential real estate market are hindered by split incentives we combine two data sources. Our main source of information is the Central Bureau of Statistics (CBS) in the Netherlands. The CBS provides information on the house, household, and actual energy consumption. Information regarding the Energy Performance Certificate (EPC) and the underlying Energy Performance Index (as introduced by the European Union) is retrieved from AgentschapNL – a governmental body tasked with the administration of energy labels in the Netherlands.

The descriptive statistics in Table 1 display that rental units are slightly more energy efficient than owner occupied dwellings, as indicated by a lower Energy Performance Certificate Index. Despite the slightly lower energy efficiency, owner-occupied homes consume less natural gas per square meter. In contrast, owner-occupied dwellings consume more electricity than the average rental unit. This may be explained by differences in household composition between rental units and owner-occupied homes. Households in owner-occupied homes tend to be larger, have more children, and are wealthier than households in rental units. Similar to previous studies we also observe differences between owner-occupied dwellings and rental units in terms of building characteristics. Owner-occupied homes are more often detached or semi-detached, whereas most rental units are apartments.

– Table 1 –

Figure 1 compares the distribution of the energy performance index, as a proxy for energy efficiency, and actual gas consumption per square meter across tenure types. Panel A of Figure 1 indicates that the average energy performance index of rental homes is somewhat lower than the energy performance index of owner occupied homes, indicating a potentially higher energy efficiency. However, inspecting the distribution of actual gas consumption per square meter in Panel B of Figure 1 shows that owner occupied homes tend to consume slightly less gas per square meter. Overall, Figure 1 shows that rental homes are slightly more energy efficient than owner occupied homes.

– Figure 1 –

The distribution of the sample of homes with an EPC label by construction year for the two tenure types, as depicted in Figure 2, shows that pre-WWII homes are more prevalent in the owner occupied sample than in the rental sample. Overall,

Figure 2 shows that the labeled homes in the rental sample are somewhat newer than the labeled homes in the owner occupied sample.

– Figure 2 –

Figure 3 depicts the average energy performance index of the labeled homes in our sample for each construction year. Not surprisingly, there is a clear relationship between the construction period and the energy efficiency of a home. Interestingly, the average energy efficiency across construction year for owner-occupied and rental homes does not seem to be very different.

– Figure 3 –

3. Methodology

Energy efficiency can be considered as a function of building characteristics and household characteristics. In an ideal situation, the identification of a potential split incentive effect can be done properly by an experimental design, where the occupant's tenure status changes from tenancy to ownership in the current house, keeping all other factors constant. However, since it is not technically possible to run this kind of experiment, we use the actual data and try to approximate this ideal experimental design. In order to investigate whether the ownership affects the energy efficiency investment in the house, we estimate the following empirical model:

$$EE_{ijt} = \beta_0 + \beta_1 * Owner_{ijt} + \beta_2 * B_{ijt} + \beta_3 * H_{ijt} + \alpha_i + \delta_j + \varepsilon_{ijt} \qquad (1)$$

where EE_{ijt} indicates the energy efficiency level of house i accommodated by household j in year *t*. The main variable of interest is the tenure status of the occupant (homeowner or renter), denoted by $Owner_{ijt}$. The coefficient of this variable represents the causal effect of being the owner of the house on the energy efficiency investment level.

Since ownership status may be correlated with other dwelling characteristics that are related to the level of energy efficiency, we also control for other building characteristics, which are denoted by B_{ijt}. For instance, owners may prefer to live in newly built homes that have a higher energy efficiency level. This may lead to a possible overestimation of the split incentive effect as owners' motivation to live in newly built homes may be related to other factors, not the higher energy efficiency level. Besides the construction year, we also control for home type and building size in the empirical model. α_i represents the unobserved building characteristics that may affect the level of energy efficiency.

Another concern about the identification of the split incentive effect is that there may be other household characteristics that determine the level of energy efficiency, which are correlated with the ownership status. For instance, the owners may have a higher income and wealth, which might enable them to afford energy efficiency investments. In this case, again, there will be an upward bias in the estimated split incentive effect. Besides income and wealth, we also control for household size, the number of elderly, children and females in the household and the working status of household members, which are denoted by H_{ijt} . δ_j represents the unobserved household characteristics. Finally, ε_{ijt} is the error term.

4. Results

4.1. Cross-sectional Analysis

We start our analysis with an Ordinary Least Squares (OLS) estimation, relating the observable characteristics of a building and household to the energy efficiency of a dwelling. Table 2 documents the results of the OLS estimations. When we do not control for other house and household characteristics, we observe a lower energy efficiency level for the owners. But when we introduce the control variables the sign of the coefficient changes and we find a significant split incentive effect as indicated by the coefficient of ownership status. Results indicate that homeownership is negatively associated with the energy performance index (controlling for observable dwelling and household characteristics, and household wealth). Therefore, as compared to renters, homeowners seem to live in homes with higher energy efficiency. The size of the coefficient indicates that owning the house as compared to renting leads to a 0.8 percent increase in the energy efficiency level. Although this effect is statistically significant, we should note that this economic effect is far below the expectations and the results documented in the previous literature.

– Table 2 –

In order to test the validity of our results, we estimate the same model for the sub-samples of homes with different construction year periods. If the estimated effect reported in Table 2 is truly related to energy efficiency investment decisions, then we should be able to report higher split incentive effects for the homes that are built earlier as they have more potential for energy efficiency improvements. In line with this expectation, the results reported in Table 3 indicate that the split incentive problem is more prominent for the older homes that are constructed before 1960s (an effect of approximately 4 to 5 percent). We also observe that the owner-occupied homes that are constructed after 1960 have slightly lower energy efficiency as compared to the rental segment of the housing market. This can be partly explained by the social and environmental concerns of the affordable housing institutions in the rental market.

– Table 3 –

So our initial results show evidence of the split incentive problem in energy efficiency investments, but the economic magnitude of the effects is far below expectations. However, there might exist some unobserved house and household related factors that are correlated with the ownership status and energy efficiency level. In that case, we might have an omitted variable bias in the estimated coefficient of ownership status. Therefore, we will next exploit the over-time variation in our data, which allows us to introduce house and household-fixed effects, as denoted by α_i *and* δ_j in equation (1).

4.2. Fixed-Effects Analysis

In order to control for unobserved dwelling specific factors that might be correlated with ownership status and energy efficiency, we switch to an analysis of the link between over-time variation in ownership status and the energy efficiency level, keeping the dwellings constant. Since we are not able to observe the over-time change in energy performance index of the house (typically households do not adopt a new label after efficiency improvements), we use the actual gas consumption per square meter as a proxy for the energy efficiency of the dwelling. Table 4 provides the results of OLS estimations using the actual gas consumption per square meter as dependent variable. Here, we observe that ownership is associated with a higher gas and electricity consumption, implying a lower energy efficiency level for homeowners. However, this result should be interpreted cautiously as there may exist many unobserved factors that can affect the actual energy consumption. Therefore, it is important to control for these unobserved factors in the analysis.

– Table 4 –

First, we focus on the mobility of the households to control for unobserved house specific factors. As a treatment group, we use a sample of homes that were occupied by tenants and then switched to owner-occupied status. The control group consists of homes that remained rental unit during the period of analysis. The results reported in

Table 5 indicate that controlling for all observable household characteristics and keeping the houses fixed, the change of ownership status from rental to owner leads to a 4.6 percent decrease in gas consumption in the subsequent years. Assuming that there is no behavioral change in energy consumption after moving to a new house, this can be considered as an almost equal increase in energy efficiency level (assuming zero rebound effect).

– Table 5 –

In order to test whether this change is associated to the behavior of new residents, we estimate the same model for electricity consumption. Since the electricity consumption in the Netherlands is mainly driven by the appliance stock of the households, we can assume that electricity consumption is mostly independent of the energy efficiency of the dwelling (except lighting), but mostly related to household-specific factors. So, if the change in energy consumption is driven by energy efficiency investments rather than behavioral factors, we do not expect a significant change in the electricity consumption level. In line with this expectation, the second column of Table 5 indicates that, controlling for other household characteristics, the change in ownership status does not effect the electricity consumption. Thus, we can conclude that the change in actual gas consumption is due to changes in the energy efficiency of the dwelling.

Another way to test whether the estimated coefficient reflects a difference in consumption behavior is to examine the homes that changed from owner-occupied to rental status (reverse direction). In Table 6, we redefine the treatment group as the homes that switched from owner-occupied to rental status, and the control group as the homes that stayed owner-occupied. Here, our hypothesis is that the estimated coefficient of ownership is not statistically different from zero, as it is not possible to decrease energy efficiency of a home when it changes from owner-occupied to rental status. The results indicate that, although the estimated coefficient is significant, it is significantly lower than the result provided in column 1 of Table 5. This implies that there might be a behavioral change in gas consumption (or because of mobility), but still there is a significant change in consumption level that can be associated to the changes in energy efficiency level.

– Table 6 –

However, one may argue that the change in energy efficiency is not mainly driven by the ownership status but instead driven by the mobility effect. We can expect that when households move to a new house, they usually prefer to make improvements in their new homes. Or, the landlords might prefer to make improvements before they rent out their dwellings. These changes in energy efficiency cannot be considered a split incentive effect. So, the estimated coefficient of change in ownership status reported in Table 5 might reflect the improvements related to the mobility of the households instead of a split incentive effect. In order to test this hypothesis, we estimate our model for two different sample specifications.

First, we use the sample of rental homes that switched to a new tenant as the treatment group and the homes that stayed with the same tenant as the control group. The results provided in column 1 indicate that this change results in a 5.4 percent reduction in actual gas consumption. In column 2, we define the treatment group as the owner-occupied homes that switched to a new owner and the control group as the homes that stayed with the same owner. Again the results indicate a 5.7 percent reduction in actual gas consumption, which can be attributed to the energy efficiency investments of new residents. This mobility effect seems to be an important determinant of energy efficiency investments. Therefore, the estimated coefficient for ownership status in Table 5 might reflect the mobility effect instead of the split incentive problem.

– Table 7 –

In order to eliminate the behavioral bias and the mobility effect from the estimations, we next control for household fixed effects. We define the treatment groups as the homes that switched from rental to owner-occupied status during the stay of the same resident (fixed households). This means that the tenants in the treatment group buy the homes they have been living in. The control group consists of the homes that stayed rental, keeping the households fixed. This sample design eliminates any behavioral differences between the owner and tenants, as we keep the households fixed. Besides, it eliminates the mobility effect, as the households do not change their addresses. The results reported in column 1 of Table 8 indicate that there is no significant split incentive effect when we control for all house and household specific factors. This result is still valid when we limit the sample to older homes as provided in column 2 of Table 8.

– Table 8 –

The result provided in Table 8 can be considered as our most robust estimation of the split incentive effect as it controls for all dwelling and household specific unobserved factors. Contradicting the previous literature on the topic, which is not able to control for these endogenous factors, we document that there is no evidence for a split incentive problem in energy efficiency investments in the housing market. On the other hand, another part of the literature provides significant evidence showing that energy efficiency investments are capitalized in the rental housing market. This can explain why landlords are equally motivated with homeowners to invest in energy efficiency.

5. Conclusion

Different split incentive problems are observed in the housing market. First, a split incentive problem may arise when the utility expenditures are included in the rental contract, potentially leading to over-consumption of energy. Second, the tenant-landlord problem may lead to underinvestment in energy efficiency improvements in the building sector, since the landlord has to invest in energy efficiency improvements and the tenant benefits in the form of a lower utility bill.

The lack of consensus in the academic literature regarding the second split incentive issue indicates the difficulty in isolating the effect. Rehdanz (2007) shows for the German housing market that homeowners spend approximately 15 percent less on energy, suggesting that homeowners are more likely to invest in energy efficiency improvements. In contrast, Meier and Rehdanz (2010) find no split incentive problem in the residential real estate market in the U.K. The authors conclude that this can be explained by differences in building type between homeowners and renters. Homeowners tend to occupy a larger share of detached and semi-detached homes, in which the heat loss is higher. Wood et al. (2012) find for Australia that homeowners spend 13 more on energy than renters. The authors conclude that differences in the institutional framework in Australia compared to Europe and North America may explain these results. In addition, Charlier (2015) documents that homeowners are more likely to invest in energy efficiency improvements than renters. Moreover, the author concludes that renters face higher energy costs due to lower building quality and, on average, have a lower income.

One conclusion that these studies have in common is the substantial differences between homeowners and renters. Homeowners tend to be richer, have larger homes, more often occupy a detached or semi-detached dwelling, and have a different household composition. All these factors are known to affect energy consumption. Consequently, previous studies in this area have been hampered by endogeneity issues. The panel data employed in this paper allows us to control for all dwelling and household specific unobserved factors. By gradually developing the analysis from a standard OLS framework to a more robust estimation in which the dwelling and household is held constant, we show that there is no evidence for a split incentive problem in energy efficiency investments in the housing market. A potential explanation for the absence of the split incentive problem in the Dutch housing market is the capitalization of energy efficiency in the rent and transaction value of dwellings.

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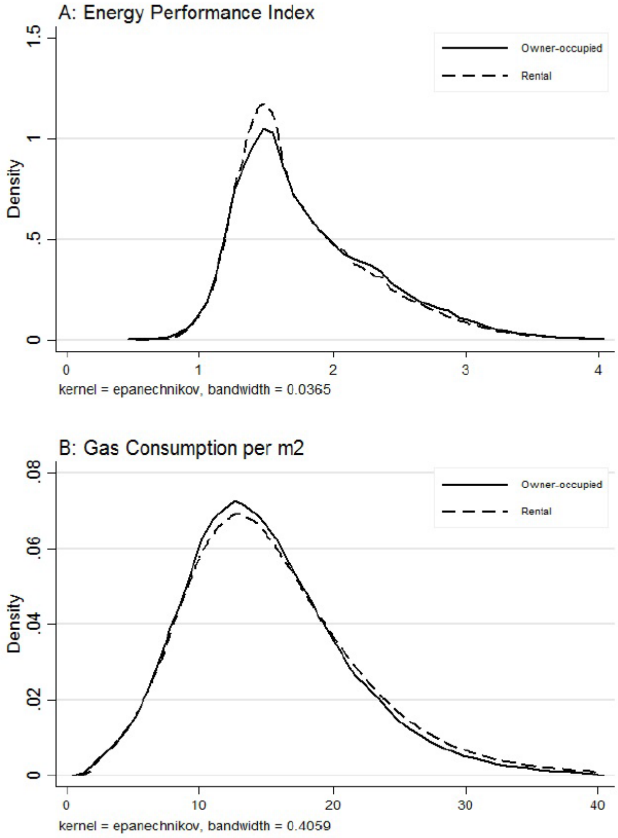
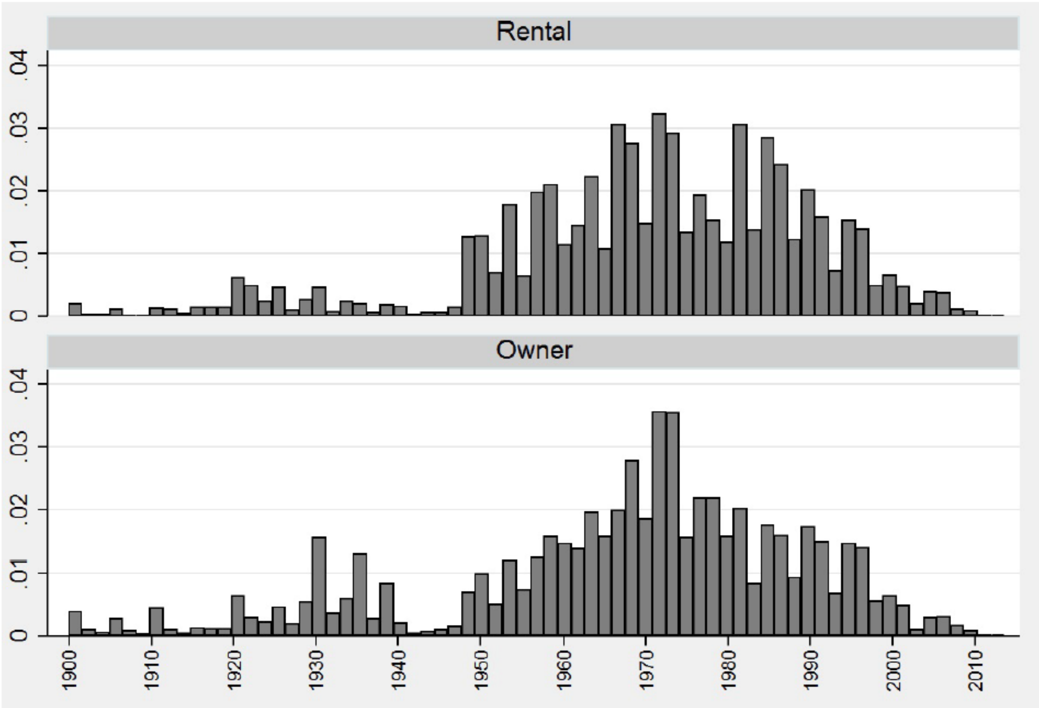
Figure 1
Distribution of Energy Efficiency by Tenure Status



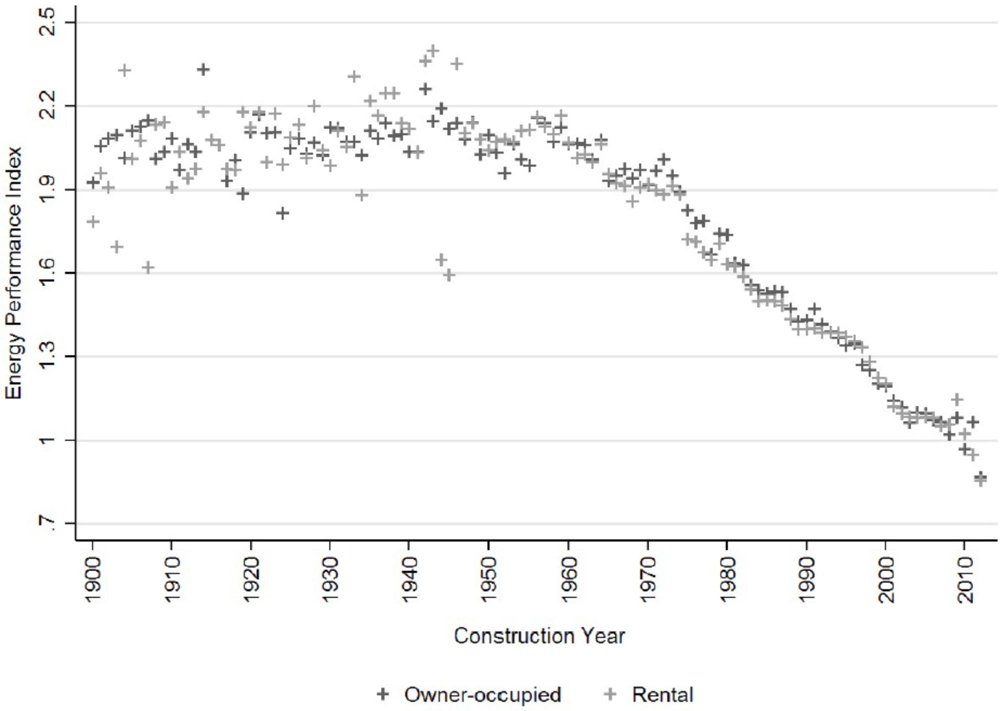
Notes: Figure shows the distribution of energy performance index and gas consumption per m^2 separately for the rental and owner-occupied homes. These figures are based on the sample of labeled dwellings that adopted an EPC between 2008 and 2013. The statistics on actual annual gas consumption are calculated based on both the cross-sectional and the time-series variation (2004, 2006, 2008, 2009, 2010, 2011). Source: Bureau of Statistics Netherlands (CBS), AgentschapNL, authors' calculations.

Figure 2
Distribution of Construction Year by Tenure Type



Notes: Figure shows the distribution of construction year of the dwelling separately for the rental and owner-occupied homes. These figures are based on the sample of labeled dwellings that adopted an EPC between 2008 and 2013. Source: Bureau of Statistics Netherlands (CBS), AgentschapNL.

Figure 3
Energy Efficiency and Construction Year by Tenure Status



Notes: Figure shows the average energy performance index level for each construction year separately for the rental and owner-occupied homes. These figures are based on the sample of labeled dwellings that adopted an EPC between 2008 and 2013. Source: Bureau of Statistics Netherlands (CBS), AgentschapNL, authors' calculations.

Table 1
Descriptive Statistics

	Owner-Occupied	Tenant-Occupied
Annual Gas Consumption (thousand cubic meters)	1.50	1.26
	(0.667)	(0.534)
Annual Electricity Consumption (thousand kwh)	3.18	2.52
	(1.595)	(1.370)
Annual Gas Consumption per square meter (cubic meter)	14.97	15.36
	(6.127)	(6.600)
EPC Index	1.81	1.77
	(0.535)	(0.501)
Dwelling Size (square meter)	102.69	82.64
	(31.05)	(20.55)
Construction Period (percent)		
1900-1930	8.00	5.50
1931-1944	5.10	1.90
1945-1959	12.30	16.40
1960-1969	18.10	19.40
1970-1979	23.90	20.30
1980-1989	18.10	21.70
1990-1999	11.70	11.70
After 2000	2.80	3.20
Dwelling Type (percent)		
Apartment	27.00	43.80
Duplex	31.50	33.90
Semi-Detached	30.60	0.20
Detached	10.90	22.00
Number of Household Members	2.29	1.90
	(1.182)	(1.101)
Number of Children	0.51	0.34
	(0.885)	(0.779)
Number of Elderly	0.22	0.48
	(0.552)	(0.695)
Number of Females	1.13	1.03
	(0.777)	(0.725)
Annual Household Net Income (in thousand euros)	32.14	23.19
	(11.61)	(9.81)
Household Wealth (in thousand euros)	113.73	21.46
	(137.80)	(50.29)
Number of Wage Earners	1.46	0.80
	(0.885)	(0.903)

Notes: Standard deviations in parentheses. All variables in percent unless indicated otherwise.

Table 2
OLS Estimations for Energy Performance Index

	(1)	(2)	(3)	(4)
Owner-occupied (1=yes)	0.002***	-0.007***	-0.004***	-0.008***
	(0.001)	(0.001)	(0.001)	(0.001)
Dwelling Characteristics	No	Yes	Yes	Yes
Household Characteristics	No	No	Yes	Yes
Household Wealth	No	No	No	Yes
Number of Observations	3,120,746	3,120,746	3,120,746	3,120,746
Number of Homes	1,188,289	1,188,289	1,188,289	1,188,289
R-squared	0.031	0.412	0.413	0.413

Notes: We limit the sample to the observations for which we have information on household wealth. The dependent variable is the logarithm of the energy performance index. A lower energy performance index indicates a higher level of energy efficiency. The years included in the analysis are 2006, 2008, 2009, and 2010 (for tenure status and household characteristics). The analysis is based on the sample of homes that adopted an energy label between 2008 and 2013. Year of observation, label adoption year and province fixed effects are included as control variables in all estimations. Dwelling characteristics are: construction period, dwelling type, and dwelling size. Household characteristics are: household net income, number of household members, number of children (age lower than 18 years), number of elderly (age larger or equal to 65 years), number of females, and working status of household members. Heteroskedasticity-robust standard errors are reported in parentheses. Standard errors are clustered at the province-year level. Significance at the 0.10, 0.05, and 0.01 level is indicated by *,**, and *** respectively.

Table 3
OLS Estimations for Energy Performance Index by Construction Period

Construction Period	(1900-1929)	(1930-1944)	(1945-1959)	(1960-1969)
Owner-occupied (1=yes)	-0.037***	-0.056***	-0.050***	0.009***
	(0.003)	(0.004)	(0.002)	(0.002)
Dwelling Characteristics	Yes	Yes	Yes	Yes
Household Characteristics	Yes	Yes	Yes	Yes
Household Wealth	Yes	Yes	Yes	Yes
Number of Observations	165,088	60,241	490,536	593,042
R-squared	0.147	0.156	0.065	0.116
Construction Period	(1970-1979)	(1980-1989)	(1990-1999)	(After 2000)
Owner-occupied (1=yes)	0.012***	0.006***	-0.005***	0.022***
	(0.001)	(0.001)	(0.001)	(0.002)
Dwelling Characteristics	Yes	Yes	Yes	Yes
Household Characteristics	Yes	Yes	Yes	Yes
Household Wealth	Yes	Yes	Yes	Yes
Number of Observations	646,881	669,142	390,087	105,729
R-squared	0.097	0.084	0.099	0.091

Notes: We limit the sample to the observations for which we have information on household wealth. The dependent variable is the logarithm of the energy performance index. A lower energy performance index indicates a higher level of energy efficiency. The years included in the analysis are 2006, 2008, 2009, and 2010 (for tenure status and household characteristics). The analysis is based on the sample of homes that adopted an energy label between 2008 and 2013. Year of observation, label adoption year and province fixed effects are included as control variables in all estimations. Dwelling characteristics are: construction period, dwelling type, and dwelling size. Household characteristics are: household net income, number of household members, number of children (age lower than 18 years), number of elderly (age larger or equal to 65 years), number of females, and working status of household members. Heteroskedasticity-robust standard errors are reported in parentheses. Standard errors are clustered at the province-year level. Significance at the 0.10, 0.05, and 0.01 level is indicated by *,**, and *** respectively.

Table 4
OLS Estimations for Gas and Electricity Consumption

	(1) Gas	(2) Electricity
Owner-occupied (1=yes)	0.071***	0.077***
	(0.001)	(0.001)
Dwelling Characteristics	Yes	Yes
Household Characteristics	Yes	Yes
Household Wealth	Yes	Yes
Number of Observations	3,072,130	3,072,130
Number of Homes	1,188,289	1,188,289
R-squared	0.252	0.370

Notes: We limit the sample to the observations for which we have information on household wealth. The dependent variable is the logarithm of the annual gas consumption per square meter (column 1) and the logarithm of electricity consumption (column 2). The years included in the analysis are 2006, 2008, 2009, and 2010 (for energy consumption, tenure status and household characteristics). The analysis is based on the sample of homes that adopted an energy label between 2008 and 2013. Year of observation, label adoption year and province fixed effects are included as control variables in all estimations. Dwelling characteristics are: construction period, dwelling type, and dwelling size. Household characteristics are: household net income, number of household members, number of children (age lower than 18 years), number of elderly (age larger or equal to 65 years), number of females, and working status of household members. Heteroskedasticity-robust standard errors are reported in parentheses. Standard errors are clustered at the province-year level. Significance at the 0.10, 0.05, and 0.01 level is indicated by *,**, and *** respectively.

Table 5
Fixed Effects Estimations for Gas and Electricity Consumption
Rental Tenant to Owner

	(1) Gas	(2) Electricity
Owner-occupied (1=yes)	-0.046***	-0.002
	(0.002)	(0.002)
Dwelling Fixed Effects	Yes	Yes
Household Characteristics	Yes	Yes
Household Wealth	Yes	Yes
Number of Observations	3,307,037	3,307,037
Number of Homes	1,188,289	1,188,289
R-squared	0.137	0.060

Notes: We limit the sample to the observations for which we have information on household wealth. The dependent variable is the logarithm of the annual gas consumption per square meter (column 1) and the logarithm of electricity consumption (column 2). The analysis is based on the sample of homes with and without an energy label. The variable "Owner-occupied" indicates the switch from tenant-occupied to owner-occupied status. We exclude the homes that stayed owner-occupied during the period of analysis and the homes that changed from owner-occupied to tenant-occupied status. This enables us to compare the homes that switched from tenant-occupied to owner-occupied with the homes that stayed tenant-occupied. The number of transitions from tenant-occupied to owner-occupied is 92,303 (6.6 percent of the sample). The years included in the analysis are 2006, 2008, 2009, and 2010 (for energy consumption, tenure status and household characteristics). Year of observation is included as a control variable in all estimations. Household characteristics are: household net income, number of household members, number of children (age lower than 18 years), number of elderly (age larger or equal to 65 years), number of females, and working status of household members. Heteroskedasticity-robust standard errors are reported in parentheses. Standard errors are clustered at the province-year level. Significance at the 0.10, 0.05, and 0.01 level is indicated by *,**, and *** respectively.

Table 6
Fixed Effects Estimations for Gas and Electricity Consumption
Owner to Rental Tenant

	(1) Gas	(2) Electricity
Owner-occupied (1=yes)	-0.012***	-0.000
	(0.003)	(0.003)
Dwelling Fixed Effects	Yes	Yes
Household Characteristics	Yes	Yes
Household Wealth	Yes	Yes
Number of Observations	1,698,867	1,698,867
Number of Homes	689,605	689,605
R-squared	0.130	0.110

Notes: We limit the sample to the observations for which we have information on household wealth. The dependent variable is the logarithm of the annual gas consumption per square meter (column 1) and the logarithm of electricity consumption (column 2). The analysis is based on the sample of homes with and without an energy label. The variable "Owner-occupied" indicates the switch from owner-occupied to tenant-occupied status. We exclude the homes that stayed tenant-occupied during the period of analysis and the homes that changed from tenant-occupied to owner-occupied status. This enables us to compare the homes that switched from owner-occupied to tenant-occupied with the homes that stayed owner-occupied. The number of transitions from owner-occupied to tenant-occupied is 29,744 (3.5 percent of the sample). The years included in the analysis are 2006, 2008, 2009, and 2010 (for energy consumption, tenure status and household characteristics). Year of observation is included as a control variable in all estimations. Household characteristics are: household net income, number of household members, number of children (age lower than 18 years), number of elderly (age larger or equal to 65 years), number of females, and working status of household members. Heteroskedasticity-robust standard errors are reported in parentheses. Standard errors are clustered at the province-year level. Significance at the 0.10, 0.05, and 0.01 level is indicated by *,**, and *** respectively.

Table 7
Fixed Effects Estimations for Gas Consumption
New Tenant or Owner

	(1) Gas	(2) Gas
New Tenant (1=yes)	-0.054***	
	(0.001)	
New Owner (1=yes)		-0.057***
		(0.001)
Dwelling Fixed Effects	Yes	Yes
Household Characteristics	Yes	Yes
Household Wealth	Yes	Yes
Number of Observations	2,938,018	1,458,292
Number of Homes	1,012,805	569,343
R-squared	0.150	0.146

Notes: We limit the sample to the observations for which we have information on household wealth. The dependent variable is the logarithm of the annual gas consumption per square meter. The analysis is based on the sample of homes with and without an energy label. The variable "New Tenant" indicates the switch from one tenant to a new tenant. We exclude the owner-occupied homes from the analysis. This enables us to compare the homes that switched to a new tenant with the homes that stayed with the same tenant. The number of transitions to a new tenant is 420,343 (35.5 percent of the sample). The variable "New Owner indicates the switch from one owner to a new owner. We exclude the tenant-occupied homes from the analysis. This enables us to compare the homes that switched to a new owner with the homes that stayed with the same owner The number of transitions to a new owner is 334,298 (48.5 percent of the sample). The years included in the analysis are 2006, 2008, 2009, and 2010 (for energy consumption, tenure status and household characteristics). Year of observation is included as a control variable in all estimations. Household characteristics are: household net income, number of household members, number of children (age lower than 18 years), number of elderly (age larger or equal to 65 years), number of females, and working status of household members. Heteroskedasticity-robust standard errors are reported in parentheses. Standard errors are clustered at the province-year level. Significance at the 0.10, 0.05, and 0.01 level is indicated by *,**, and *** respectively.

Table 8
Fixed Effects Estimations for Gas Consumption
Tenant to Owner, and Household Fixed

	(1)	(2)
	Gas	Gas
Construction Period	(1900-2010)	(1900-1959)
Owner-occupied (1=yes)	-0.002	0.005
	(0.002)	(0.004)
Dwelling Fixed Effects	Yes	Yes
Household Fixed Effects	Yes	Yes
Household Characteristics	Yes	Yes
Household Wealth	Yes	Yes
Number of Observations	1,698,867	1,698,867
Number of Homes	689,605	689,605
R-squared	0.130	0.110

Notes: We limit the sample to the observations for which we have information on household wealth. The dependent variable is the logarithm of the annual gas consumption per square meter. The analysis is based on the sample of homes with and without an energy label. The variable "Owner-occupied" indicates the switch from tenant-occupied to owner-occupied status for the same household at the same home. We exclude the owner-occupied homes and the homes that switched from owner-occupied to tenant-occupied status from the analysis. This enables us to compare the homes that switched from tenant-occupied to owner-occupied with the homes that stayed tenant-occupied, keeping the household constant. The number of transitions from tenant-occupied to owner-occupiedin the same house is 15,179 (2 percent of the sample). Column 2 is based on the sample of homes that were constructed between 1900 and 1959. The number of transistions from tenant-occupied to owner-occupied in the same house (older homes) is 4,583 (2.5 percent of the sample). The years included in the analysis are 2006, 2008, 2009, and 2010 (for energy consumption, tenure status and household characteristics). Year of observation is included as a control variable in all estimations. Household characteristics are: household net income, number of household members, number of children (age lower than 18 years), number of elderly (age larger or equal to 65 years), number of females, and working status of household members. Heteroskedasticity-robust standard errors are reported in parentheses. Standard errors are clustered at the province-year level. Significance at the 0.10, 0.05, and 0.01 level is indicated by *,**, and *** respectively.