Capitalization of Energy Efficiency in the Housing Market

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Motivation

- 40% of total energy consumption in EU is used by residential sector
- Reasons for underinvestment in energy efficiency in housing sector
  - Uncertainty about the financial returns of efficiency investments
    - energy efficiency$\rightarrow$ energy costs $\rightarrow$ house price
  - Information asymmetry between seller and buyer

Research Question

- What is the value of energy efficiency in the housing market?
- What is the role of information transparency (EPC) on the valuation of energy efficiency?

Literature

- Use of Energy Performance Certificates
  - Compare price of houses with different energy ratings
  - Brounen and Kok (2011) for the Netherlands, Hyland et al. (2013) for Ireland, Kahn and Kok (2014) for California
- Other Studies
  - Thorsnes and Bishop (2013) and Koirala et al. (2014) examine the capitalization of building standards

Literature

- Limitations of the available literature
  - Unobserved house characteristics that are correlated with measures of energy efficiency
  - Multicollinearity: leading to insignificant and/or theoretically incorrect estimates for the coefficients of energy efficiency (Atkinson and Halvorsen, 1984).
  - Measurement error
  - Effect of information transparency on capitalization rate?
  - Over-time variation in the capitalization rate?

Empirical Specification

$$Log(Price_i) = \beta_0 + \beta_1 Log(E_i) + \beta_j X_i + \alpha_n + t_i + \varepsilon_i \qquad (1)$$

- $Log(Price_i)$: Log of house price
- $Log(E_i)$: Log of energy performance indicator
- X_i: Dwelling characteristics (household characteristics)
- α_n: neighborhood fixed-effects
- t_i: transaction year fixed-effects

Data

- 30,036 single-family houses transacted with EPC
- 103,834 single-family houses transacted without EPC
- Variables
  - House Price
  - Energy Performance Index (houses with EPC)
  - House characteristics
  - Actual gas consumption (2004-2011)
  - Household characteristics (2004-2011)

Data

- House characteristics
  - neighborhood
  - transaction year
  - construction year
  - dwelling size - volume, and lot size
  - dwelling type
  - internal and external quality
  - number of floors, number of rooms
  - indoor parking place, type of parking place
  - location of the dwelling relative to centre, road, park, water and forest.

Descriptive Statistics

Energielabel woning

Afgegeven conform de Regeling energieprestatie gebouwen.

Veel besparingsmogelijkheden

Weinig besparingsmogelijkheden

D
(zie toelichting in bijlage)

Uw woning

Labelklasse maakt vergelijking met woning(en) van het volgende type mogelijk.

Rijwoning - Tussen

Gebruiksoppervlak	**Adviesbedrijf**
131,0 m³	Advies BV
Opnamedatum	**Inschrijfnummer**
01-01-2010	
Energielabel geldig tot	**Handtekening**
01-01-2020	
Afmeldnummer	

Straat
Dorpstraat
Nummer/toevoeging
1
Postcode
9999 AA
Woonplaats
Hoofdstad

Energielabel op basis van een ander representatief gebouw of gebouwdeel? -
Adres representatief gebouw of gebouwdeel: -

Standaard energiegebruik voor uw woning

Energiegebruik maakt vergelijking met andere woning(en) mogelijk.

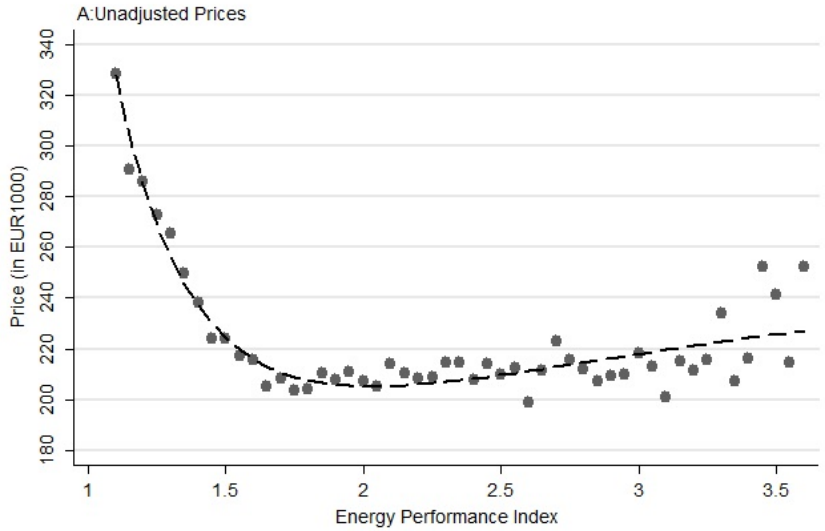
- Het standaard energiegebruik is de hoeveelheid primaire energie die nodig is voor de verwarming van uw woning, de productie van warm water, ventilatie en verlichting.
- De eventuele opbrengst van een zonnepaneel wordt hiervan afgetrokken.
- Het energiegebruik wordt berekend op basis van de bouwkundige eigenschappen en de installaties van uw woning.
- Bij de berekening wordt uitgegaan van het gemiddelde Nederlandse klimaat, een gemiddeld aantal bewoners en gemiddeld bewonersgedrag.
- Het standaard energiegebruik wordt uitgedrukt in de eenheid 'megajoules', dit wordt uitgesplitst naar elektriciteit (kWh), gas (m³) en warmte (GJ).

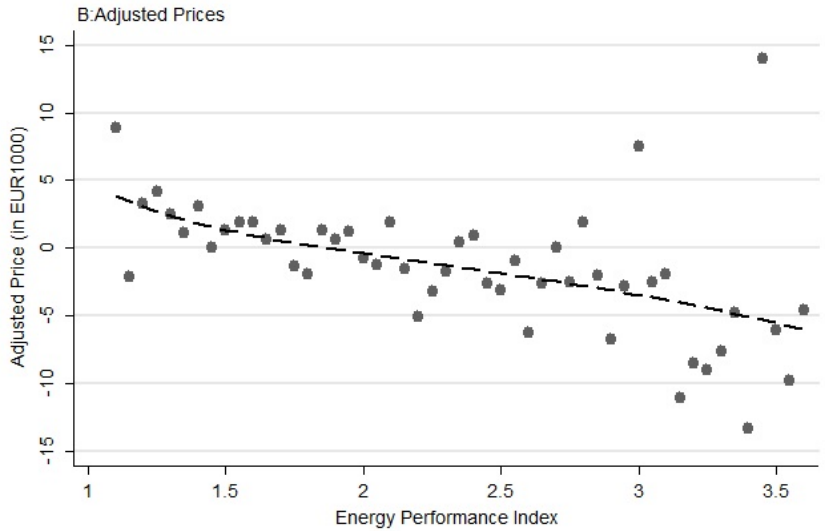
76705 MJ
(megajoules)

1037 **kWh** (elektriciteit)
1909 **m³** (gas)
0 **GJ** (warmte)

Descriptive Statistics

Transaction Prices and the Level of Energy Efficiency





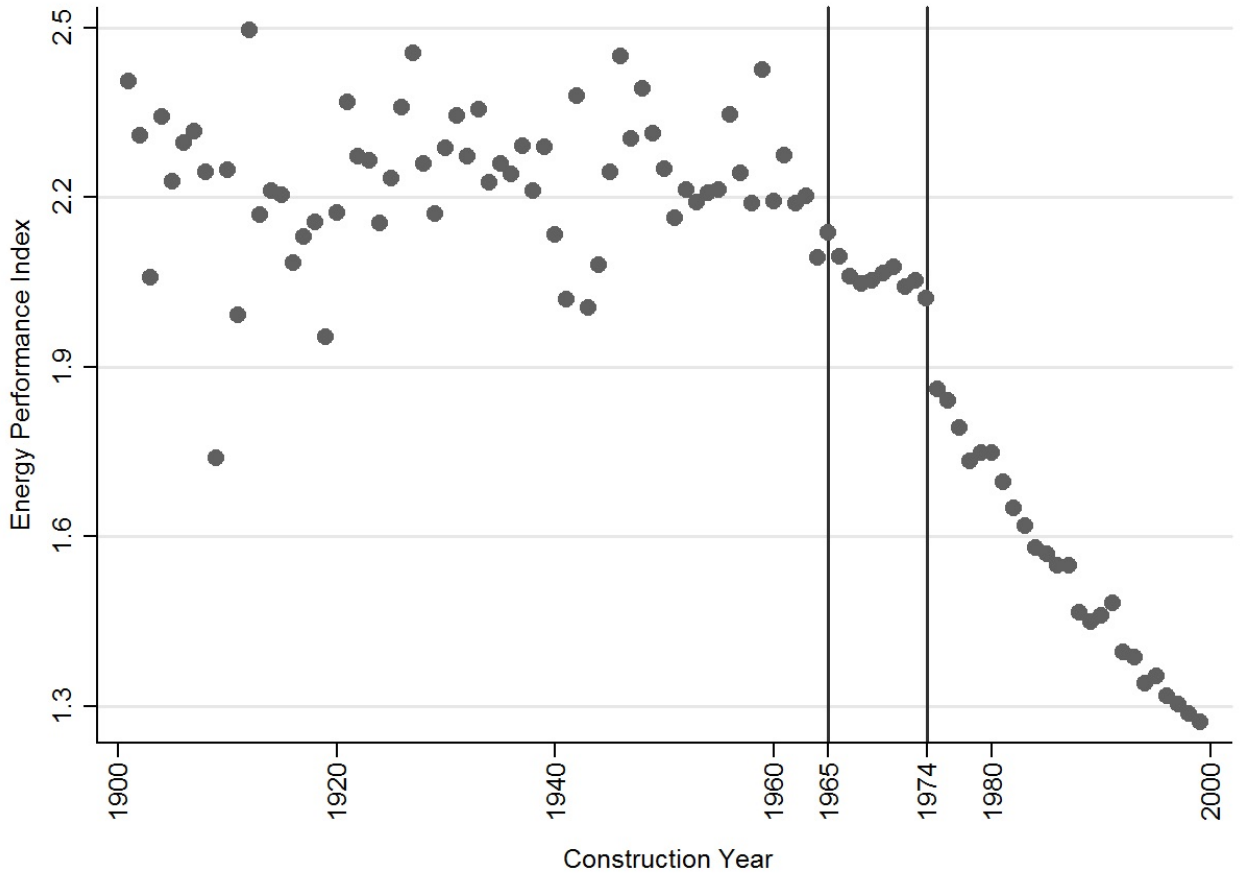
OLS Estimations

	(1)	(2)	(3)	(4)
Log(Energy Performance Index)	-0.235***	-0.106***	-0.052***	-0.048***
	[0.009]	[0.004]	[0.005]	[0.005]
Dwelling Characteristics	No	Yes	Yes	Yes
Construction Year	No	No	Yes	Yes
R^2	0.106	0.833	0.841	0.843
Number of observations	30,036	30,036	30,036	30,036

*Construction year is included as a third order polynomial in specification (3). In specification (4), we included as dummy variables.

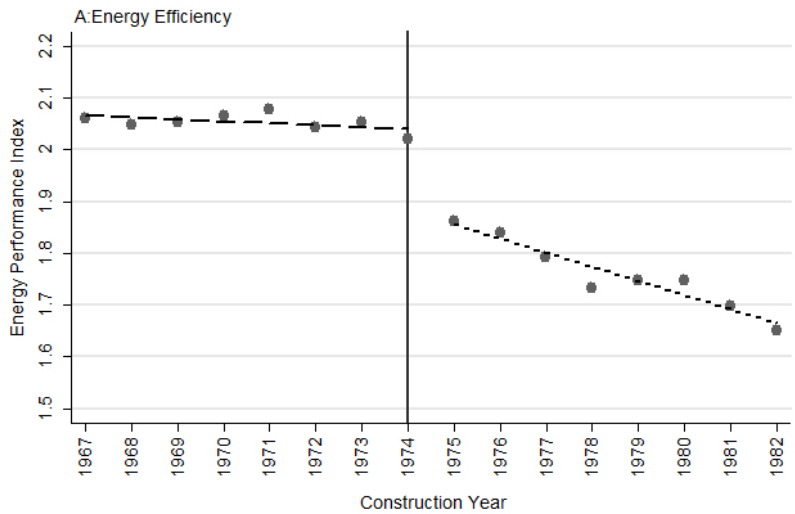
Instrumental Variable Approach

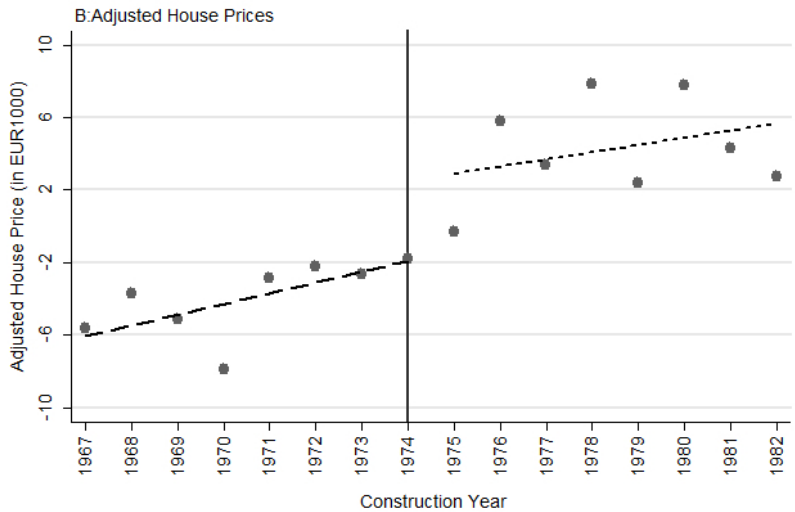
Efficiency Level of the Dwellings by Year of Construction



Instrumental Variable Approach: 1973-74 Oil Shock

Energy Efficiency and Price of the Dwellings Constructed Before and After 1974



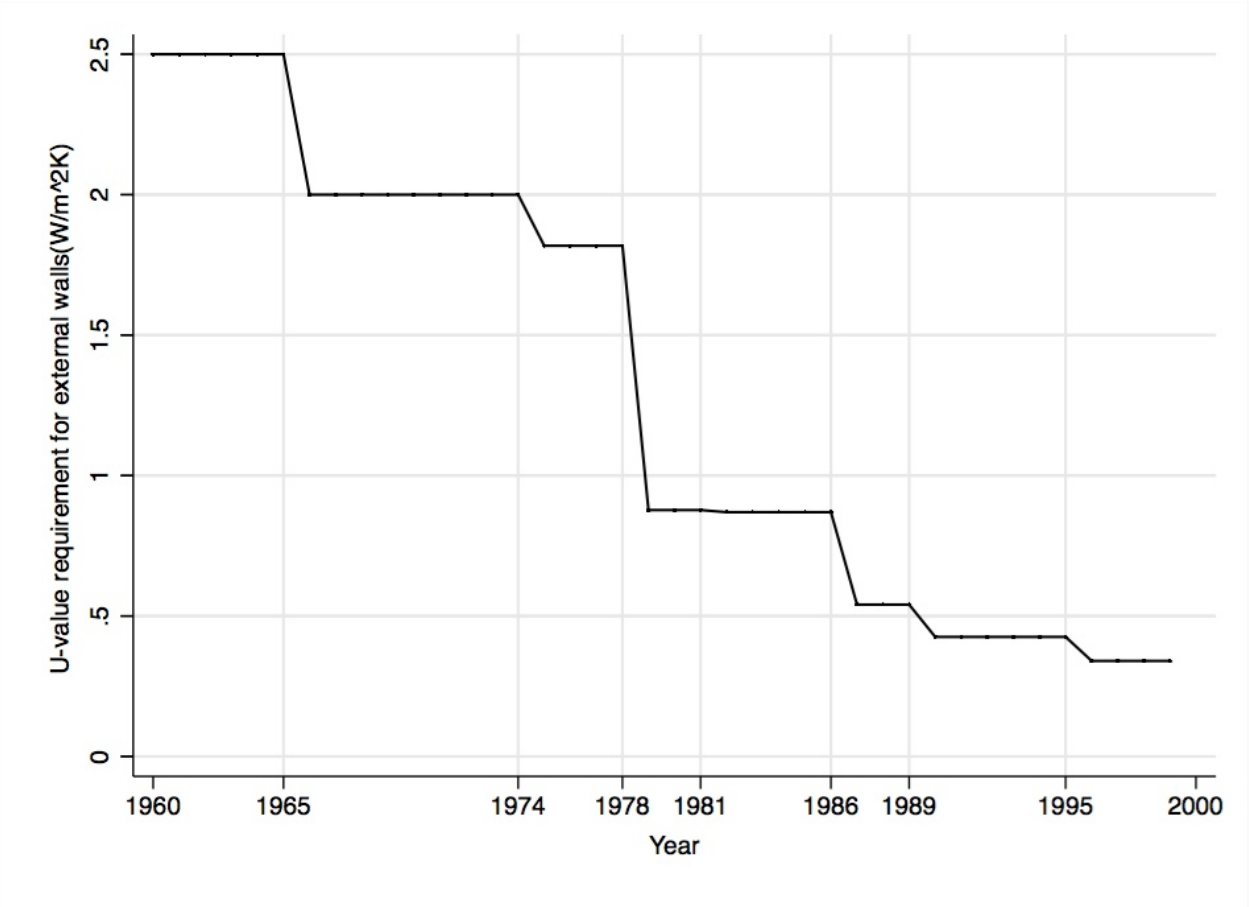


Instrumental Variable Approach: 1973-74 Oil Shock

Construction Period	(1967-1982)	(1959-1990)	(1950-1999)
Log(Energy Performance Index)	-0.227*** [0.067]	-0.185*** [0.065]	-0.198*** [0.048]
Dwelling Characteristics	Yes	Yes	Yes
Construction Year	Yes	Yes	Yes
R^2	0.846	0.848	0.851
First Stage			
D^{1974}	-0.080*** [0.007]	-0.071*** [0.005]	-0.060*** [0.004]
Number of observations	12,513	20,270	25,311

Instrumental Variable Approach: Building Codes

Over-time Variation in the Stringency of Building Codes



Instrumental Variable Approach: Building Codes

Log(Energy Performance Index)	-0.214*** [0.061]
Dwelling Characteristics	Yes
Construction Year	Yes
R^2	0.835
First Stage Results	
U-value	0.071*** [0.005]
Number of observations	30,036

Impact of Information Provision

- Compare the market value of energy efficiency for labeled and non-labeled dwellings
  - Use actual gas consumption (per m^2) as a proxy for the energy efficiency
  - Control for household characteristics
    - number of household members
    - number of children (age$<$18)
    - number of elderly (age$>$65)
    - number of females
    - household net income
  - Use "evolution of building codes" as IV

Impact of Information Provision

OLS Estimations

	(1)	(2)	(3)	(4)	(5)
Log(Actual Gas Cons. per m^2)	-0.071***	0.049***	0.112***	0.105***	0.086***
	[0.004]	[0.002]	[0.002]	[0.002]	[0.004]
Dwelling Characteristics	No	Yes	Yes	Yes	Yes
Construction Year	No	No	Yes	Yes	Yes
Household Characteristics	No	No	No	Yes	Yes
R^2	0.010	0.755	0.773	0.793	0.852
Number of observations	103,834	103,834	103,834	103,834	23,187

***In column (5), we estimate the same model for the sample of certified dwellings.**

Impact of Information Provision

IV Estimation Results for Non-certified and Certified Dwellings

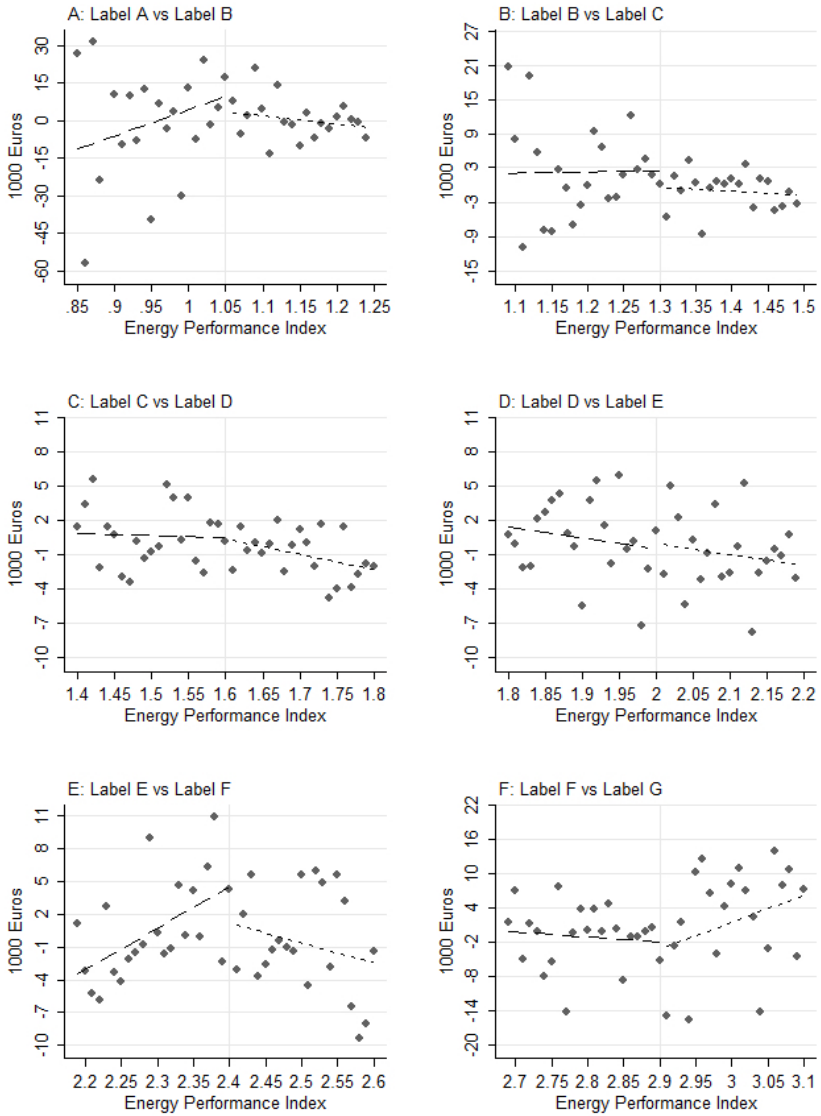
	(Non-certified)	(Certified)	(Certified)
Log(Actual Gas Cons. per m^2)	-0.239***	-0.195**	
	[0.040]	[0.079]	
Log(Energy Performance Index)			-0.185***
			[0.070]
Dwelling Characteristics	Yes	Yes	Yes
Construction Year	Yes	Yes	Yes
Household Characteristics	Yes	Yes	Yes
R^2	0.740	0.818	0.844
First Stage Results			
U-value	0.068***	0.065***	0.069***
	[0.004]	[0.008]	[0.006]
Number of observations	103,834	23,187	23,187

Impact of Information Provision

- Examine whether the energy label itself has an additional impact on the transaction price.
  - Apply a regression discontinuity (RD) approach based on the rule that is used to assign dwellings in energy efficiency classes

Impact of Information Provision

Transaction Price (adjusted) by Label Category and Energy Performance Index



Impact of Information Provision

Regression Discontinuity Estimation Results for Label Effect

	(A-B)	(B-C)	(C-D)	(D-E)	(E-F)	(F-G)
$D^{L.label}$=1	-0.013	-0.012	-0.002	-0.000	- 0.007	-0.015
	[0.027]	[0.008]	[0.006]	[0.008]	[0.010]	[0.018]
Log(EPI)	0.171	-0.011	-0.019	-0.052	0.300**	-0.055
	[0.280]	[0.070]	[0.054]	[0.081]	[0.129]	[0.274]
Log(EPI)*$D^{L.label}$	-0.433	-0.060	-0.088	-0.037	-0.494**	0.530
	[0.305]	[0.093]	[0.081]	[0.146]	[0.212]	[0.451]
Dwelling Characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Construction Year	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.881	0.872	0.854	0.852	0.858	0.856
Number of obs.	1,461	6,879	11,009	6,899	4,606	2,146

Impact of Information Provision

- There is not a significant evidence suggesting a higher capitalization rate for dwellings that transacted with an energy performance certificate.
- Labeling itself does not lead to a significant change in buyer's valuation of the dwelling

Over-time Variation in the Value of Energy Efficiency

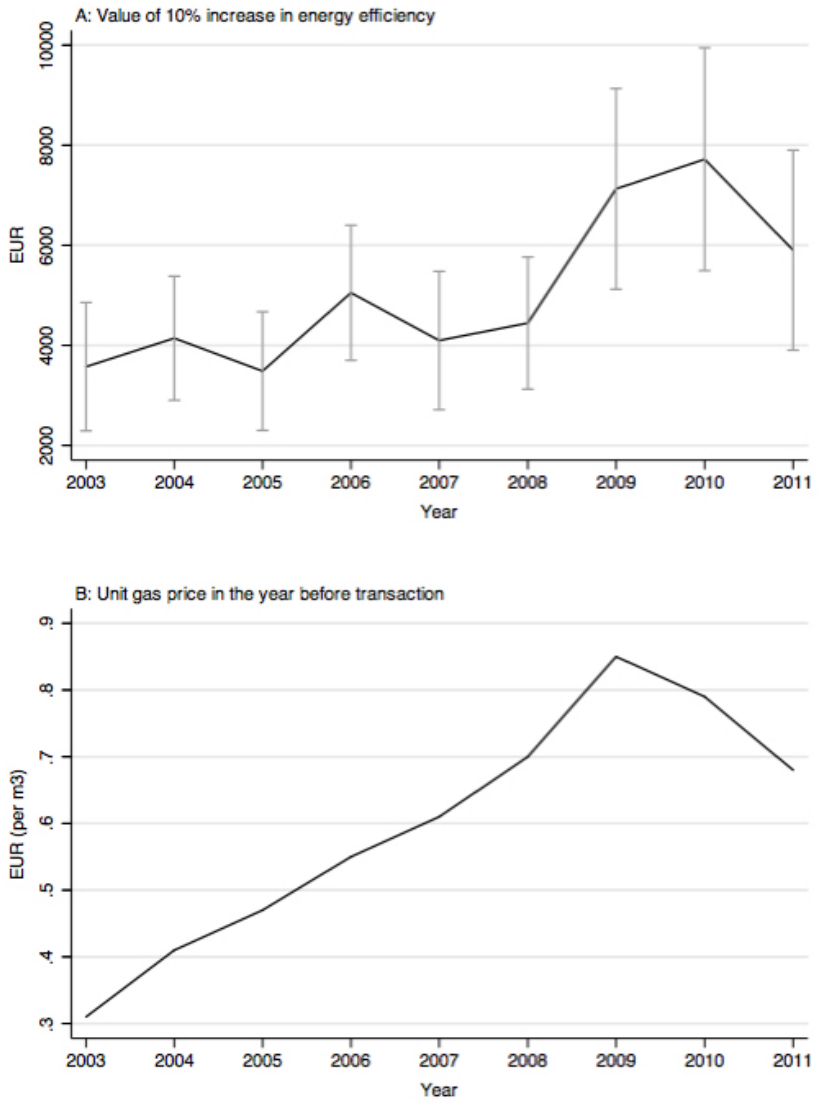
- Examine how the value of energy efficiency varies over-time.
  - Use the sample of houses that transacted between 2003-2011 without EPC
  - Estimated the same model for each year seperately

Over-time Variation in the Value of Energy Efficiency

Year	Log(Gas Cons. per m^2)	N
2003	-0.156*** [0.056]	42,346
2004	-0.177*** [0.053]	42,847
2005	-0.144*** [0.049]	48,702
2006	-0.202*** [0.054]	48,632
2007	-0.160*** [0.054]	47,976
2008	-0.175*** [0.052]	39,030
2009	-0.302*** [0.085]	28,742
2010	-0.319*** [0.092]	30,768
2011	-0.248*** [0.084]	28,936

Over-time Variation in the Value of Energy Efficiency

Value of Energy Efficiency and Gas Prices



Over-time Variation in the Value of Energy Efficiency

- Value of energy efficiency has doubled from 2003 to 2011
  - increase in energy prices,
  - general influence of policies and information campaigns stressing the importance of energy efficiency.

Benefits and Costs of Energy Efficiency Investments

- If the energy requirement of a dwelling is reduced by half;
  - Its market value increases by around €23,000 for the average dwelling in our sample.
  - Besides, €535 annual saving in energy costs
- Costs:
  - Required saving measures cost around €15,000 (MilieuCentraal).

Benefits and Costs of Energy Efficiency Investments

- Why energy efficiency investments in the housing sector are below the optimal level?
  - Additional costs
    - Nuisance during the retrofit work
    - Information costs
  - Risk of undervaluation in the market
  - Liquidity constraints
  - Future discounting behavior

Policy Implications

- The results may be used to enhance the public awareness regarding the financial benefits of energy efficiency investments.
- The financial benefits that homeowners can derive from energy efficiency improvements can be incorporated into the energy performance certification programs.