The usage of a hedonic pricing model to calculate the impact of energy efficiency on house prices

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ABSTRACT

In this paper an attempt is made to calculate the impact of energy efficiency on the house prices in two districts in the city of Groningen, the Netherlands. In Korrewegwijk the presence of a central heating unit positively influences the house price. Window insulation, the installation year and the property of the unit are not significant for both districts. Other insulation is insignificant for Beijum. So, not all energy saving characteristics are capitalized in the ask price. Possibly, the usage of an energy label can solve this capitalization problem.

JEL code: R32

Key words: hedonic pricing; house prices; energy efficiency

Since January 1st, 2008 the selling party of a house in the Netherlands is obliged to have a so called energy label[1]. This label is an indication of the energy costs of a house. The label uses 7 classes, labeled A/green for the most efficient houses to G/red for the most inefficient houses.

Although it is obliged to show the energy label of the house if a potential buyer asks for it, not many house owners have them yet. Because of this non-availability of the labels the authors of this paper are investigating the effect of energy efficiency on housing prices. The aim of the research is to investigate whether there is an impact of energy efficiency and if this effect is different for a new versus an old area. This is tested for two different neighborhoods in the city of Groningen, the Netherlands, namely Korrewegwijk, with houses built around 1930, and Beijum, with house built around the 80's.

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[1] If a house is younger than 10 years, this label is not obliged.

The goal is to test whether insulation and the presence and characteristics of a central heating influences the house prices differently in the two areas. Dependent on the results it can be attractive for the house owner to get such an energy label.

The paper starts with a literature review about relevant research and the use of hedonic pricing models. In the second section the methodology that is used during the paper is explained, followed by a description of the data. The fourth section consists of the analysis of the data. The limitations of the research are presented in section five. The paper ends with the conclusions.

I. Literature review

Comparing studies that use hedonic models is complicated because of the fact that studies define and measure variables differently. Sirmans, Macpherson, and Zietz (2005) discuss approximately 125 studies in their article. They mention the 20 most appearing characteristics, and the times that they are positively, negatively, or not significant. Among the 20 variables are besides lot size and square feet, also the natural logarithm of lot size and the logarithm of square feet.

The hedonic pricing model is often estimated in semi-log form with the natural log of price used as the dependent variable. The reason for this is that, for example the value added of a bedroom might be greater for a $500,000 house than for a $100,000 house. Then the coefficient estimates allow one to calculate the percentage change in price for a one-unit change in the given variable.

Sirmans, Macpherson, and Zietz (2005) also categorize all the characteristics into eight categories, namely construction and structure, house internal features, house external amenities, environmental – natural, environmental – neighborhood and location, environmental – public service, marketing, occupancy and selling, and financial issues.

This paper focuses on the issues of internal and external features and construction and structure, and therefore, the top 5 frequently used characteristics per these categories are shown in table 1.

Table I: House characteristics used in previous research

Variable	Appearances	# positive	# negative	# not significant
Constuction and structure				
Age	78	7	63	8
Square feet	69	62	4	3
Lot size	52	45	0	7
# Bathrooms	40	34	1	5
Bedrooms	40	21	9	10
House internal features				
Fireplace	57	43	3	11
Full baths	37	31	1	5
Air-conditioning	37	34	1	2
Basement	21	15	1	5
Half baths	7	6	0	1
Hardwood floors	7	5	0	2
House external amenities				
Garage spaces	61	48	0	13
Pool	31	27	0	4
Deck	12	10	0	2
Porch	9	5	0	4
Garage	4	3	0	1
Carport	4	1	1	2

Sirmans, Macpherson, and Zietz (2005) find among other things that slanted versus flat roof positively affects the selling price and that not having attic space negatively affects the selling price.

Palmquist (1984) argues that that the number of square feet of living space would not simply have a linear effect on price. As the number of square feet increases, construction costs do not increase proportionally. To allow for this non-linearity he also included the square of the living area in the regression. After diagnostic testing of their model, MacDonald and Veeman (1996) came to a similar conclusion, and therefore they included the cubed specification of interior space in their model.

A research by MacDonald and Veeman (1996) showed that some 85 percent of variation in Edmonton house prices is explained by the simple OLS version of the model where interior space, finished basement, views of river valley or ravines, garage, and centre are positively significant explanators of the sale price of houses, and age and distance from the city are negatively significant explanators.

It can be seen from the review that a lot of research has been done on general properties of real estate and their influence of the price. Lately, because of social debates, there is much focus on the effects of railroads and nearby airports on the price of properties (e.g. Dekkers and Van der Straaten (2008) on the monetary valuation of aircraft noise or

Strand and Vågnes (2001) on the relationship between property values and railroad proximity).

While energy savings is also a heavily discussed social issue, only a few articles discuss the impact of energy saving attributes on the price of real estate.
Dinan and Miranowski (1989) find a significant positive effect of energy savings on the price of real estate. They find that for an average house, a reduction of the energy bill by $1 increases the house price with $11.63, concluding that energy saving investments does increase house prices.

Banfi, Farsi, Filippini, and Jakob (2008) found after asking 305 apartment tenants and house owners that they significantly value energy-saving attributes.

Longstreth (1986) focuses on the impact of energy conserving home improvements with respect to the type of buyers. She concluded that for middle and low income and middle and low educated buyers there is a significant effect of energy conserving durables on the house price. For age and for family size results were mixed. She points out that not every buyer capitalized energy saving durables into the house price when valuing the house. Longstreth argues that the valuation of the energy saving durables depends much on the judgment of the buyer and accuracy of the information. As a result, much can be gained by clearly communicating energy saving attributes of the house and making it more clearly to understand by a usage of energy labels. While Longstreth (1986) pointed this out 24 years ago, there are still almost no energy labels provided for houses.

II. Methodology

Hedonic pricing models are used to value real assets through a bundle of underlying characteristics of these assets. This paper applies the hedonic pricing model on the housing market and the characteristics of these houses. Using this information, an ordinary least squares regression (OLS) is performed on the data to test the impact and significance of the various attributes. The focus in this paper is on the energy saving characteristics of the houses.

Of course, other relevant variables also need to be included in the regression, because these variables do explain a large part in the variability of the house price. Including these relevant variables leads to an isolation of the energy saving, this makes the estimate of the impact more accurate.

A basic assumption of the hedonic model is that each asset can be described by a vector of its characteristics:

$$H = (h_1, h_2, ..., h_n) \quad (1)$$

Where H is the house and h_i is the i-th characteristic of the house. The function for the price can be derived from this:

$$P = P(h_1, h_2, ..., h_n) \quad (2)$$

Where P is the ask price of the house in this model. Of most interest are the derivatives of this formula with respect to the specific characteristics.

$$\frac{\partial P}{\partial h_i} = P_{h_i} \quad (3)$$

Here P_{hi} represents the effect on the asking price of a house. Within the OLS regression this would be presented by the various betas for the specific characteristics. The model being tested has the following functional form

$$P = \beta o + \beta i(h_1, h_2, ..., h_n) \quad (2)$$

The assumptions underlying ordinary least squares are tested, as well as the collinearity between the attributes. To test if the relationship between the price and the house characteristics is well specified, a Ramsey Regression Equation Specification Error Test (RESET) test is used. The Jarque-Bera test is used to test for the normality of the residuals. The mean of the residuals will always be zero provided that there is a constant.

III. Data and Hypotheses

The choice of attributes to be valued is based on a priori reasoning of the importance of the housing characteristics, evidence from previous studies, and the data available from the sample.

The Dutch real estate website funda.nl is the source of the data. The website contains houses of all brokers listed with the NVM, which covers the vast majority of the Dutch housing market. There are 86 and 81 houses for sale in respectively Korrewegwijk and Beijum.

A first selection is made on the price, houses ranging from €125,000 until €225,000 are selected. This is done for two reasons. The majority of the houses are priced within this range. In Beijum there are no houses listed above €225,000 and to keep this in line with respect to Korrewegwijk this is the maximum. In Korrewegwijk there is one neglected house worth less than €125,000. Therefore, the minimum is set at €125,000. Because of the small range of prices, and the similarity of the houses within the area, the price is used as the dependent variable and not the natural logarithm of the price.

From the available houses in Korrewegwijk two houses are removed from the sample. One house is removed because of the fact that it is a new project without buyer costs and one of them because it is a monument.

As a result of this selection 58 and 71 houses where left in Beijum and Korrewegwijk. From these the first 50 based on placement date are selected for both districts.

The characteristics of the houses shown in the first column of table II are used as the input in our model. The second column of table 2 shows the measurement level of the corresponding attribute. If the attribute is nominal, the following columns contain the dummies and in parentheses the times the variable is found. If the measurement level is interval or ratio the following columns contain the minimum, maximum, average, and standard deviation of the attribute.

Table II: Descriptives of the characteristics*

Characteristic	Measurement scale	Minimum	Maximum	Average	Standard deviation	Hypothesis
Independent variable						
Price	Ratio	125,000 / 129,500	217,500 / 219,000	159,298 / 158,320	20,195.41 / 23,295.52	
Dependent variables						
Construction year	Interval	1928 / 1976	1939 / 1993	1932.06 / 1982.66	2.48 / 3.07	+
Square meters	Ratio	55 / 70	110 / 150	76.98 / 109.2	15.74 / 18.47	+
Cubic meters	Ratio	160 / 133	325 / 450	227.42 / 320.58	49.10 / 63.50	+
Indoor storage	Ratio	0 / 0	7 / 15	0.24 / 1.32	1.06 / 3.47	+
# Bedrooms	Ratio	1 / 1	4 / 5	2.12 / 3.30	0.85 / 0.91	+
Bedroom space	Ratio	6 / 16	47 / 69	19.72 / 35.41	10.45 / 10.97	+
Living room space	Ratio	15 / 23	42 / 55	31.79 / 36.24	5.13 / 7.24	+
Garden	Ratio	0 / 0	144 / 165	31.08 / 62.2	38.58 / 31.64	+
Balcony	Nominal	No (23) / (47)	Yes (27) / (3)			+
Building type˜	Nominal	Upstairs (24)	Ground Floor (26)			+
		Townhouse (33)	Corner (17)			+
Roof type	Nominal	Flat roof (35) / (8)	Slanted roof (15) / (42)			+
External storage	Nominal	No (7) / (2)	Yes (43) / (48)			+

Bath	Nominal	No (37) / (26)	Yes (13) / (24)			+
Kitchen	Nominal	Open plan (14) / (47)	Closed plan (36) / (3)			+
Specific dependent variables						
Window insulation	Nominal	Not double-glazed (33) / (26)	Double-glazed (17) / (24)			+
Other insulation	Nominal	No (50) / (26)	Yes (0) / (24)			+
Central heating	Nominal	No central heating (16) / (0)	Central heating (34) / (50)			+
Installation year central heating	Interval	1993 / 1981	2009 / 2009	2002.85 / 2000.42	4.34 / 5.58	+
Property of central heating	Nominal	Lease (13˚) / (9)	Ownership (21˚) / (41)			≠

* The data is presented in such a way that the numbers before the slash (/) are from Korrewegwijk and the number after the slash are from Beijum. If the attribute is nominal, the third and fourth column contain the dummies options and in parentheses the times the variable is present.
˜ The first row represents the building types of Korrewegwijk and the second row of Beijum.
˚ Where all the dummies add up to 50, this does not hold for the property of central heating in Korrewegwijk, because there are only 34 houses with a central heating.

The *building type dummy* is the only variable that has a different meaning for both the areas. In Korrewegwijk a 1 represents a ground for house and a 0 represents an upstairs building. In Beijum a 1 represents a corner type building where a 0 represents a townhouse. The roof type dummy differentiates between flat and slanted roof. The *slanted roof dummy* consists of several types of roofs, for example gabled roofs, side gabled roofs and a few different sorts. There is no dummy included for the roofing, because every flat roof has roofing felt, and every slanted roof has tiles. So, both attributes are perfectly correlated, and therefore, the roofing type has no additional explanatory power. In this paper the *number of bedrooms* and the *total square feet* of the rooms are used, because the authors think that it is the combination of both that best predicts the house prices. The *window insulation dummy* of not double-glazed consists of partially double glazed windows. The *other insulation dummy* is 1 if the house has roof, wall, or floor insulation. The *no central heating dummy* contains gas stoves, central fire places, and air circulation for heating in combination with a gas boiler or geyser for warm water.

The brand of the central heating is not included because this is not reported for every house, and there a lot of different brands[2].

[2] Thirteen different brand were found; AGPO, ATAG, AWB, Blauwe Engel, Bosch, Fasto, Feroli, Intergas, Junkers Eurostar, Nefit, Radson, Remeha and Vailliant.

There is no inclusion of distance-to variables, because of the fact that the two neighborhoods are independently investigated, assuming that the distance to a particular object is not of interest for the specific areas.

Every dummy is created in such a way, that it increases the value of the house when the value for the dummy is 1, according to the hypotheses, which are based on the relevant literature and common knowledge. Only the hypotheses of the specific characteristics for this research are discussed in more detail.

Window insulation: It is expected that presence of double-glazed windows has a positive effect on the house price.

H_1: β_1=0 versus H_1: β_1>0

Other insulation[3]: It is expected that presence of roof, wall, or floor insulation increases the residential value.

H_2: β_2=0 versus H_2: β_2>0

Central heating[4]: It is expected that central heating increases house prices compared with gas stoves.

H_3: β_2=0 versus H_3: β_3>0

Installation year central heating: It is thought that a newer central heating system is more worth than an older one, and therefore a positive slope is expected.

H_4: β_2=0 versus H_4: β_4>0

Property of central heating: This dummy is included to find out if the property of a central heating influences the value of a house. Of course, it does not influence the energy savings, but it could influence the residential value.

H_5: β_2=0 versus H_5: $\beta_5\neq$0

IV. Analysis

This part of the paper starts with a discussion of the collinearity between the attributes. Subsection B discusses the regression model for Korrewegwijk, where subsection C discusses that for Beijum. In subsection B and C the price effect of the energy saving attributes are compared with the initial cost of the investment. This idea is similar to that of Daniere (1994) and Banfi et al. (2008) were the willingness-to-pay for housing attributes is calculated. The final subsection discusses the assumptions of both regression models.

[3] This hypothesis is not tested for Korrewegwijk, because there is no house in this area with other insulation.
[4] This hypothesis is not tested for Beijum, because every house in this area has a central heating unit.

A. Multicollinearity

Before the OLS regression can be started, the characteristics have to be tested for multicollinearity. The correlation matrices for the attributes are presented in appendix A. It can be seen from table AI that the *square meters*, the *cubic meters*, the *living room space*, the *bedroom space*, and the *number of bedrooms* is highly correlated for Korrewegwijk. It makes sense that one of the two variables about the bedrooms has to be deleted. Therefore the *bed room space* is omitted from the model. This also has to do with the fact the bed room space together with the *living room space* are close to the *square meter*, and thus, *living room space* is also omitted from the model. Finally, the *cubic meters* are omitted from the model, because of the clear relationship with the *square meters*. For similar reasons *bedroom space, living room space*, and *cubic meters* are omitted for Beijum, where the variables are also highly correlated, as shown in table AII.

With respect to the attributes *building type*, *balcony*, and *garden* nothing is done yet, but caution is need. However, the correlation makes sense, because only one upstairs house does not has a balcony and no upstairs house has a garden and only 4 ground floor houses have a balcony, further all ground floor houses have a garden.

B. Ordinary Least Squares Korrewegwijk and implications

Table III shows the results from the OLS regression of the house characteristics on price.

Table III Regression coefficients on housing prices in Korrewegwijk

	All observations		Central heating only	
Variable	Coefficient	P-value	Coefficient	P-value
Square meters	470.63	0.006***	1,173.65	0.009***
Slanted roof	3,812.58	0.287	-476.98	0.945
# Bedrooms	10,455.99	0.002***	8,754.19	0.151
Balcony	14,140.13	0.007***	11,667.98	0.298
Bath	4,693.94	0.182	4,102.60	0.536
Central heating˜	7,360.13	0.043**		
Closed kitchen	-4,687.30	0.198	-3,792.67	0.620
Construction year	-644.41	0.281	-3,416.67	0.023**
Double-glazed	3,174.99	0.311	14,118.57	0.033**
External storage	-1,155.93	0.814	-12,364.35	0.130
Indoor storage	-434.94	0.779	-545.39	0.904
Ground floor	26,611.58	0.000***	17,928.17	0.128
Installation year central heating°			378.16	0.593
Property of central heating°			9,248.30	0.317
Intercept	1320,493.00		5881,401.00	
Adjusted R^2 (in %)	76.00		81.27	
n	50		34	

F-statistic	0.000***	0.000***

* / ** / *** Significant at a 10% / 5% / 1% level
° These attributes are only included in the regression where houses with central heating are selected.
˜ Central heating is the selection criteria for the second analysis and therefore not included in the second regression.

The model is significant at the 1% level and is able to explain a good proportion of the house price with an adjusted R^2 of 76%.

In the first regression, the number of bedrooms and the building type are significant at the 1% level. Because a linear function is used, the coefficients show the direct price effect of the change in variables. The direction of both coefficients is positive, a ground floor type house compared to an upstairs house adds €26,611.58 to the value of the house. This is a large proportion of the total value of the house. The directions of the significant variables are all positive as hypothesized.

Double-glazed windows do not significantly influence the price of houses in Korrewegwijk. This can be due to the accuracy of the data. Every house that was double glazed receives a 1 for the dummy, where partially double-glazed houses receive a 0. Partially double-glazed means for some houses that almost every window is double-glazed, while for other houses this means only one window is double-glazed.

Central heating is significant at a 5% level. The presence of a central heating unit adds €7,360.13 to the value of the house. The average purchase price of installing a central heating unit and radiators is €3,430. The average payback period is 8.3 year, as calculated by the Dutch Environment Central Foundation, due to the effect of average cost reductions on the energy bill after installing central heating. The presence of central heating is capitalized in the house price for €7,360.13. This means that the investment directly pays out, assuming no large influences from the time value of money.

The second regression analyses the effect for the houses with central heating. The installation year and the property of the central heating unit both do not have significant effects. Newer central heating units do not have a positive effect on the house price. Nevertheless, double-glazed windows become a significant attribute for houses with central heating. This can be due to the fact that double-glazing has more effect on the energy efficiency when using central heating, because a central heating unit heats all rooms in a house and radiators are often placed below a window.

In complete contrast with the expectation construction year is significantly negatively influencing the price.

C. Ordinary Least Squares Beijum and implications

Table IV shows the results for the regression of house characteristics on the house price in Beijum, no second regression is done because every house in Beijum has central heating.

Table IV: Regression coefficients on house prices Beijum

Variable	Coefficient	P-value
Square meters	670.21	0.011**
Slanted roof	3,355.97	0.665
Other insulation	8,822.79	0.256
Garden	28.90	0.821
External storage	-789.23	0.966
Double-glazed	-7,874.67	0.261
Corner type	14,843.27	0.056*
Construction year	2,313.33	0.058*
Closed kitchen	-28,839.39	0.196
Bath	1,115.59	0.861
Balcony	-8,834.42	0.464
# Bedrooms	5,575.82	0.300
Indoor storage	-61.41	0.946
Property of central heating	-7,070.05	0.455
Installation year central heating	-331.30	0.575
Intercept	-3858,601.00	
Adjusted R^2 (in %)	52.12	
n	50	
F-statistic		0.001***
* / ** / *** Significant at a 10% / 5% / 1% level		

Again the model is significant at the 1% level, although the adjusted R^2 is lower than in the previous regression. Still, the model is able to explain a large part of the variations in the price with an adjusted R^2 of 52.18%. Again square meters and the house type are significant. In this case a corner type house adds €14,843.27 to the price in comparison to a townhouse. The construction year is positively significantly influencing the house price.

Energy saving characteristics have no significant influences on the price. The installation year of the central heating units ranges from 1981 to 2009, a range of 28 years. Nevertheless, most installation years are closely to the mean value of 2000, with a few lower outliers. Differences between newer central heating units in extra energy efficiencies and write offs can be too small to have a significant effect on the value.

The authors have no direction in the alternative hypothesis about the effect of owning the central heating unit. The data shows no significant effect for the property of the central heating.

D. Robustness and assumptions OLS

To test the model for Korrewegwijk for any misspecification a Ramsey RESET test is used. The *P-values* of the *F-statistic* and the *Likelihood ratio* are 0.589 and 0.521, respectively, so the null-hypothesis that the model is well-specified is not rejected. The *P-value* of the Jarque-Bera test is 0.607, and therefore, the null-hypothesis that the residuals are normally distributed is not rejected.

The Ramsey reset test for Beijum resulted in a rejection of the null-hypothesis that the model is well-specified, both the *F-statistic* and *Likelihood ratio* are highly significant with a *P-value* of 0.006 and 0.000, respectively.

The Jarque-Bera test has a P-value of 0.634 and therefore the null-hypothesis that the residuals are normally distributed is not rejected.

V. Limitations of the research

A large amount of dummy variables are used in the regression model. This has to do with the fact of the lack of availability of the data. On this point of data selection can be gained, because some dummies can be replaced with continuous data (e.g. replace the balcony dummy with the size of the balcony, replace the external storage dummy with the size of the shed).

On drawback of the analysis is the size of the sample of n=50, where a larger sample size is always better. Another major drawback is the use of the ask price of the house. Of course, it would be better to use the selling price, or maybe the bid price, of the house to calculate what people really are willing to pay for energy saving attributes. Nevertheless, the authors expect that the usage of the ask price does not lead to influential biases.

VI. Conclusions and suggestions for further research.

For Korrewegwijk the square meters of the building, the number of bedrooms, the presence of a balcony, the building type and the presence of a central heating unit increases the residential value. Double glazed do not have a significant effect on the house price. For the houses in Korrewegwijk with central heating the effect of double-glazed window is positively significant, where the construction year negatively affects the house price, and the installation year and the property of the unit are not significant.

Therefore, house owners in Korrewegwijk would benefit from installing central heating by an increase in their residential value and lower energy bills.

For Beijum the square meters of the building, the building type, and the construction year all positively affect the residential value. No significant effects where found for window insulation, other insulation, installation year, and the property of the unit are not significant.

Clearly, not all energy saving characteristics are capitalized in the ask price. This may be due to the intransparency of the potential monthly savings of those attributes. Therefore, the authors think that the usage of an energy label will improve the capitalization of energy saving characteristics on the value of houses.

Appendix A. Correlation Matrices

Table A1: Correlation matrix for Korrewegwijk

	Square meters	Building type	Balcony	Construction year	External storage	# bedrooms	Roof type	Garden	Central heating	Bedroom space	Living room space	Cubic meters
Square meters	1.00											
Building type	0.25	1.00										
Balcony	0.02	**0.86**°	1.00									
Construction year	0.29	0.20	-0.26	1.00								
External storage	-0.01	-0.26	0.30	-0.17	1.00							
# bedrooms	**0.66***	-0.18	0.34	0.15	0.20	1.00						
Roof type	-0.11	-0.11	0.04	0.17	**0.60˜**	-0.40	1.00					
Garden	0.19	**0.74**°	**0.75**°	0.45	-0.16	0.01	-0.02	1.00				
Central heating	-0.26	-0.05	0.13	-0.12	0.04	**-0.50˜**	0.30	-0.30	1.00			
Bedroom space	**0.59***	-0.24	0.37	0.00	0.23	**0.93***	-0.28	-0.07	-0.40	1.00		
Living room space	**0.67***	0.33	-0.05	**0.61˜**	-0.10	0.18	0.15	0.35	0.09	0.08	1.00	
Cubic meters	**0.85***	0.30	-0.05	0.22	0.01	**0.58***	-0.01	0.28	-0.29	**0.54***	**0.57***	1.00

The table contains only the attributes that have a correlation of 0.5 or higher or -0.5 or lower.
***** Attributes related to size
° Attributes related to building type and outside space
˜ Attributes that do not have a relevant relation

Table AII: Correlation matrix for Beijum

	Cubic meters	# bedrooms	Bedroom space	Square meters
Cubic meters	1.00			
# bedrooms	**0.61***	1.00		
Bedroom space	**0.67***	**0.88***	1.00	
Square meters	**0.88***	**0.65***	**0.69***	1.00

The table contains only the attributes that have a correlation of 0.5 or higher or -0.5 or lower.
***** Attributes related to size

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