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Abstract

Nuclear power plants existences have been well debated since the 70s (Swedish radiation safety authority, 2014). Accidents, risk and presence connected to nuclear power plants have been part of many studies around the world. Recent studies have shown a connection between prices of houses and the distance and presence of nuclear power plant in a surronding area of the house. This paper uses Hedonic price modelling to investigate the willingness to pay for an increased distance to the Swedish nuclear power plant, Forsmark. For the dependent variable selling price was used and the independent variables were number of rooms, living area, other area, lot size, selling year, building year and distance to Forsmark. The findings of the study were a positive relation between distance from Forsmark and house prices within a 25-kilometer range. The study also tested a possible Fukushima effect that prices would go down after the Fukushima accident in 2011. The study didn't find a statistical Fukushima effect. Further research should be done to look deeper into the effects of having a nuclear power plant in a surrounding area of a house in Sweden. Such research should include more independent variables, observations and also the other nuclear power plants located in Sweden.

Sammanfattning

Kärnkraft som energikälla har varit ett omdiskuterat ämne sedan sjuttiotalet (Swedish radiation safety authority, 2014). Risken och skadorna av en olycka, hur avfallet ska hanteras och lagras är några av alla frågor. Tidigare studier har visat på ett samband mellan huspriser och såväl närvaro av ett kärnkraftverk i närheten som avstånd till ett närliggande kärnkraftverk. Denna studie har tittat på försäljningspriser på hus inom 25 kilometers avstånd från Forsmarks kärnkraftverk på den svenska östkusten. Studien har baserats på två frågor, om avståndet till Forsmark påverkar huspriser inom 25 kilometer från Forsmark och om det kan urskiljas en negativ Fukushima effekt på huspriser kring Forsmark, i samband med Fukushima olyckan i Japan 2011. Frågorna testades genom en hedonisk prismodell. Modellen byggde på priset i logaritm som beroende variabel med boarea, biarea, antal rum, tomtstorlek, försäljningsår, byggår och avstånd till Forsmark som oberoende variabler. Där både boarea och avstånd inkluderades som andragradspolynom och försäljningsår som binär variabel, de resterande oberoende variablerna inkulderades som linjära. Resultatet visar att avståndet har en positiv inverkan på priset inom 25 kilometer. I resultatet kan inte en signifikant Fukushimaeffekt ses. För att dra vidare slutsatser bör fler studier på ämnet göras där fler variabler, observationer och eventuellt de två övriga kärnkraftverk i Sverige inkluderas.

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1. Introduction

Nuclear reactors as a power source have been a topic of discussion since the early 70s (Swedish radiation safety authority, 2014). Its effect on the surrounding area after an accident together with the risk of an accident and the uncertainty concerning storage of the nuclear waste makes it an interesting subject to look deeper into. A way to do so is to look into the population's choices to see how they make decision around this subject. This paper will use house prices to see how people value distance to a nuclear power plant. Under the introduction a background description will be presented aswell as the research questions.

1.1. Background

Sweden got its first nuclear power plant in 1954. It was started for research purpose and placed 30 meters below the ground. The first commercial reactor was built outside of Stockholm and was introduced in 1963. Since then the production has extended (Swedish radiation safety authority, 2014). Today the production in Sweden corresponds to about 50 % of the total energy consumption in Sweden (Swedish radiation safety authority, 2013).

There are running nuclear power plants located in three different places in Sweden. One of them is Forsmark nuclear power plant. Currently Forsmark has three reactors, which all were built in the 80s. Together they can produce 20-25 terawatt hours per year. Forsmark has over 1000 employees (Vattenfall, 2014).

Using nuclear power in a production setting is not free from risk. Several accidents at nuclear power plants have taken place since nuclear power started to be used. Maybe one of the most common known accidents was the accident in Chernobyl in former Soviet Union in 1986 (Swedish radiation safety authority, 2014). The accident was caused by a series of safety flaws that eventually caused a meltdown and an explosion. Radioactive waste travelled with air and spread widely. Even safety devices in Sweden reacted on increased levels of radioactive substances (Sjöstrand 2014).

Another well-known accident took place 2011 in Fukushima, Japan. The accident was caused from a tsunami that was triggered from an earthquake. The tsunami made the cooling system to break and a meltdown occured. The Fukushima accident gave headlines over the world and made the discussion of safety in connection to nuclear power production blossom again (Swedish radiation safety authority, 2014). The effects of the accident were largely contamination of the surrounding ground. Where many houses had to be evacuated, and still a large number of the evacuated areas is not safe to be in (Swedish radiation safety authority, 2014, (2)).

The waste from the production has to be taken care of in a proper way. The waste is still radioactive and therefore dangerous. There are plans of building a final disposal facility near the site in Forsmark, an operation planned to start 2019. The new disposal facility will store the most dangerous kind of waste (SKB, 2014).

Several issues connected to nuclear power plants have made it a well-debated topic. Discussions about the effects of an accident but also the risk of a production of power based on nuclear reactions started in the 70s (Swedish radiation safety authority, 2014). Since then there has been a discussion that has bloomed with every incident connected to nuclear power.

The public opinion in Sweden about nuclear power could affect the choices that people make. Public opinion has changed over the years. In an investigation made by the SOM-institute in Gothenburg the share that wanted to phase out nuclear power and those who want to phase out but still use the existing reactors until they are discarded as an energy source has increased from 39 % in 2010 up to 50 % in 2013. The share that want to keep the reactors running and build up to 10 new reactors and those who want to increase the number of reactors decreased from 44 % in 2010 to 33 % in 2013 (Hedberg and Holmberg, 2014).

Basically, there are two different angles to consider when estimating peoples opinions in the matter, the effects of an accident and the constant risk of an accident. Since accidents are not that common, especially not in Sweden, the experienced risk is easier to look into. There are several ways of doing so; it could be evaluated directly (with interviews for example) or indirectly (through peoples actions).

1.2. Research question and hypotheses

In this paper implicit prices will be calculate for houses within a 25 kilometres range from Forsmark nuclear power plant. Two questions will be tested;

1. Will house prices increase when distance to Forsmark increases?
2. Does the Fukushima accident in 2011 affect house prices within 25 kilometres of Forsmark?

The hypothesis for the first question is that there will be a relation between house prices and distance to a nuclear power plant. The hypothesis is also that the relation will be positive; so that house prices will increase when distance to Forsmark increases, house prices increases aswell. The hypothesis of whether or not the Fukushima accident affects prices is that it does. So that after the Fukushima accident, it is hypothesized that house prices near Forsmark decreased.

To test the two above stated hypotheses Hedonic pricing model will be used. Due to time limitation the demand function for the characteristics will not be calculated. The model will be estimated with the software Gretl. The estimation will be based on a data set of 413 observations. The observations are selling prices of houses within a 25 kilometers range from Forsmark nuclear power plant. Each observation contains of information on the selling price of the house and a number of attributes of the houses. The attributes used in this paper are number of rooms, living area, other area, lot size, year of construction, sales year and the distance to Forsmark from the house. The attributes will be used as explanatory variables for house prices in the chosen area.

1.3. Structure of paper

The structure of the paper is a review of previous studies in the area, a method section where the basics of the method and reliability of the result is presented, data description including explanation about the data and area description connected to the data, econometric result where the calculated model is presented, the result will be analysed and finally a wider discussion about the result and ideas for improvement will conclude the text.

2. Literature review

In this section a review of previous studies will follow, previous studies within the area of Hedonic pricing and nuclear power. The studies that are presented here are for importance to the subject since they've looked into how to capture nuclear power plants as an amenity. In this section studies are presented that have used Hedonic price model as a way to capture peoples willingness to pay for the amenity of nuclear power plants.

A study in the United States used people's actions to see how they experienced risk connected to nuclear power. The scope was how prices of land were affected by closeness to nuclear power plants. The results showed that there was a closeness effect. Both plants that were running and new plants affected prices. The effect measured up to 10 % decrease of the value of land when a new plant was installed (Folland and Hough, 2000).

Perceived risk could also be different if the nuclear power plant is operating or not. A study based on two different plants in California showed a relation that was negative in first degree and the polynomial of degree two was positive. Meaning they've used distance in quadratic form and given the negative sign followed by a positive the effect of distance on house prices are of U-shaped form. The interpretation of this would be as distance increase house prices decrease to a certain point and then increase. The relation was seen both at the running plant and the plant that was shut down. Squared distance was, however, only significant in the relation to the closed plant. Employees of nuclear power plants seem to have less fear and more willingness to live close by the power plant than others (Clark et al.1997).

Several approaches can be used to study a potential effect of having a nuclear power plant nearby. In Japan researchers found that between July 2010 and July 2011 land prices decreased as an effect of the radioactive contamination of the land. The contamination of land was an effect of the Fukushima accident on the 11th of March 2011. The study showed a negative impact in a range of 80 km from the nuclear power plant in Fukushima on land prices due to contamination (Yamane et. al. 2013).

In the surrounding area to Fukushima (within a range of 80 kilometres) the land prices had a positive correlation with the distance to Fukushima. That means that when distance increases land prices increase too. For both years included in the study there was a positive relation, but the coefficient increased from 1.99E-01 in 2010 to 3.81E-02 in 2011, which means that after the Fukushima accident the distance to Fukushima nuclear power plant had a bigger influence on land prices (Yamane et. al. 2013).

It is not just the nuclear production that can make a perceived risk, the spent nuclear fuel has to be stored somewhere. How this affect prices has been tested at the nuclear power plant Rancho Seco, where both distance to the plant as well as announcement of building intentions and visual reminders were included in the analysis. The results showed that there was a positive relation between prices and all three variables, although announcement of intention of construction waste site, was insignificant (Clark and Allison, 1999).

In Clark et. al. (1997) the nuclear power plant effect is captured by using distance from property to plant and squared distance. Distance was also used in an interaction with each possible year sold in. Clark and Alison (1999) only used distance in linear form. In Folland and Hough (2000) nuclear is captured by a number of variables such as the presence of a nuclear power plant in a certain area, distance less than 60 miles from plant to a Basic Trading Area, if the plant is operating or soon to be and a few other control variables for nuclear power. In Yamane et. al. (2013) distance to Fukushima was in logarithmic form. In Clark and Nieves (1994) nuclear power is captured by the density per 1000 square miles of nuclear power plants either in operation or in a final stage of construction.

How a possible nuclear power plant effect is captured in the literature is mainly in two forms. Either as a dummy variable for the presence of a nuclear power plant within a certain range or as a distance variable. Which form to use depends on several things, for example what the model is supposed to capture and what kind of data is available.

Table 1, previous research summary

Author	Land and published year	Adjusted R^2	Variable	Sign
Clark and Nieves	United States, 1994	0.58	A dummy for nuclear power plant either in operation or in final stages of construction, *NFDNSNUP*.	-
Folland and Hough	United States, 2000	0.93 (in the Box-Cox model)	Presence of a nuclear power plant, *nuclear,* dummy variable.	-
Yamane et. al.	Japan, 2013	0.82 (OLS-model, 2011)	Distance to Fukushima.	+
Clark et. al.	United States, 1997	0.78	Distance to Rancho Seco.	+
			Squared distance to Rancho Seco.	-
		0.64	Distance to Diablo Canyon.	+
			Squared distance to Diablo Canyon.	-
Clark and Allison	United States, 1999	0.83	Distance to Ranco Seco plant.	+

By summing up the papers mentioned in recent studies a pattern can be seen. A pattern that nuclear power plants near a house may decrease the value of the house. A conclusion could be that a nuclear power plant is a disamenity that people are less willing to pay for to have in the neighbourhood of their home.

3. Method

In this section the chosen method will be described and the tests that will be made on the model will be explained.

3.1. Hedonic price model

House prices have become a popular way to use in investigating values of environmental non-market goods (Haab and McConell, 2002). Consumers' preferences will determine the price a house is sold for. The price depends on the characteristics of the house and how consumers value them (Palmquist, 2005). Characteristics of a good can determine the price when a good is differentiated.

A product that is heterogeneous or differentiated is different from others in the same product category but sell on the same market. The products within the same category have a wide range of differentiated characteristics but still belong in the same category. If two products are totally identical except for one characteristic, the price difference can be seen as a way to estimate an indirect willingness to pay for that characteristic by consumers (Taylor, 2003).

Hedonic prices are prices for goods that are quality-differentiated. Hedonic price models are a non-market valuation, a way to value the characteristic that doesn't have its own market. Houses are the most common goods to use in modelling hedonic prices (Haab and McConnell, 2002). Houses are usually different from each other in many ways. They have a different number of rooms, lot size, distance to a city, schools and so on. All things that could determine differences in house prices and therefore should be considered to be included in the Hedonic price model.

Hedonic pricing is often used to measure environmental amenities, amenities are not provided by an own market, examples of amenities are air pollution, noise pollution or distance to a waste site (Haab and McConnell, 2002). Hedonic pricing gives an idea of how the amenity affects prices of houses, and how consumers are willing to pay to avoid them. The amenites mentioned can be seen as negative, amenities can also be positive such as open landscape.

A price can be explained as a set of hedonic prices that show the price of each characteristic or attribute connected to the good (Rosen, 1974).

In a market for differentiated products the price can be described by a number of characteristics or attributes of the product, $z = (z_1, z_2 \ldots z_n)$. Each *z* represents an attribute of the product. Together the attributes affect the price, $P(z) = P\,(z_1, z_2 \ldots z_n)$ (Rosen, 1974).

A consumer is assumed to always maximise utility. So when consumers choose which good to buy it is related to total maximum utility including the utility consumers get from other goods. Utility functions are written as $Utility = U\,(x, z_1, z_2 \ldots z_n)$, where x represents all other goods (and held constant in this calculation) and *z* is an attribute of a good *y*. Maximising this function given a consumers budget constraint an optimal bundle of attributes given a budget can be calculated (Rosen, 1974).

The implicit price of an attribute is also considered to be the willingness to pay by the consumer for that special attribute. The implicit price of a characteristic is the partial derivative of price with respect to that specific characteristic, $\frac{\partial P}{\partial z_i}$. This shows how price changes with a one-unit change in z_i (Taylor, 2003).

Hedonic price modelling often contains of two stages. The first stage is to collect information on prices and characteristic of the good that is looked into. The information is used to make an estimated hedonic price function. This analysis gives an opportunity to analyse the indirect prices of characteristics and the willingness to pay by consumers. In the second stage demand functions are calculated for the characteristics; this stage requires more data and is therefor a more complex analysis (Taylor, 2003).

When choosing the functional form of the hedonic price model, there are some things to consider. The function is rarely linear and therefore a non-linear form has to be used. That means that the marginal price is not constant. It is often best to use semi-log, where not all variables are in logarithmic form, or log-log, both sides are logarithmic, form when estimating the hedonic model regarding house prices (Taylor, 2003).

When a function is linear, an increase in the independent variable makes an equally large change in the dependent variable regardless of the size of *x*. When a function is non-linear the change in the dependent variable can be different depending on the size of *x*. For example the change in y can be different when *x* increase from one to two than when x increases from eight to nine although the changes in *x* are the same. The natural logarithms slope is steep in the beginning of the curve and gets flatter when x increases. Logarithms give a percentage change, and they can be used on y and/or x in a function. Another way to handle non-linearity is to use polynomial of a variable, so that for example there is both x and x^2 in the function, this is another way to let the variable change differently (Stock and Watson, 2012).

The implicit price when a semi-log functional form is calculated as follows;

Equation: $\ln P = \beta_0 + \sum \beta_i z_i$

Implicit price: $\frac{\delta P}{\delta z_i} = \beta_i \times P$

(Taylor, 2003)

The dependent variable is often the sale price of residential houses. In some papers other variables such as tax assessor, are used for the dependent variable, due to the difficulties of collecting sale prices. But that could lead to a non-correlation of the independent variables and doesn't correspond in the same extent (Taylor, 2003).

The independent variables have to explain variation in the dependent to belong in the function. It is good to have as many as possible that can explain variation, but it is not always possible to get data for all things that explain variation. But characteristics that don't affect the price should not be included, there could be characteristics that does vary between products but doesn't affect price. Most papers divides characteristics into three different categories, these are characteristics of the house, of the neighbourhood and distance to a recreation area or as in this case to a nuclear power plant (Taylor, 2003).

Binary variable, or dummy variable, is a variable that can only take two values, one or zero. It can be used as for example one for female or zero for male. When a binary variable is in the regression the interpretation of the coefficient is not the same as for a continuous variable. When dealing with continuous variables the coefficient is referred to as a slope for the variable, or the slope of the regression when everything else is hold constant. But in the case of binary variables the coefficient is mostly referred to as a coefficient multiplying the variable, since it only can take two values there will not be a line so there will neither be a slope (Stock and Watson, 2012).

Binary variables also need to be handled so that a dummy variable trap can be avoided. If both female and male variables are included in a model there will be a case of perfect multicollinearity scince every obersvation falls into one of these two categories, and the variables vary perfectly with each other. To avoid this dummy variable trap one of the two can be excluded. So if there are two binary variables, one for female and one for male it's enough to only include one of them (Stock and Watson, 2012).

The estimation method that is used is ordinary least squares, OLS, one of the most commonly used estimation methods. OLS gives coefficients so that the regression line, the estimated function, is as close to the observed values as possible. The idea is to find coefficients that can explain Y as good as possible with as little deflection as possible (Stock and Watson, 2012).

The multiple regression models take the following form:

$$Y = \beta_0 + \sum \beta_i * X_i + u_i, i = 1 \ldots, n$$

In this model β_0 is the intercept and this value are the same for all observations. The sum of all independent variables multiplied with their respective coefficients are $\sum \beta_i * X_i$ and u_i represents the elements the model cannot explain in the variation in the dependent variable (Stock and Watson, 2012).

When the function contains of polynominal or quadratic variables the signs of the relevant coefficents determine the shape of the function. When the coefficient associated with the first degree variable is negative and the one associated with the second degree variable is positive the shape is as a U. An inverted U appears when the opposite situation prevails i.e. a coefficient associated with the polynominal of first degree is positive and the one associated with the second degree variable is negative (Studenmund, 2006).

When analysing the coefficient of nuclear variables (in this case the distance variable) it is worth to keep in mind that even though the first thought might be that there should be a positive coefficient a negative coefficient may coccur capturing employees who wish to live near the workplace (Clark et.al. 1997). There can be people that have other preferences that dosen't fit in the model or the effect that is trying to be captured. These things need to be kept in mind when analysing the result.

3.2. Determining the relevance of the model

How well the estimated model describes the observed values of the dependent variable can be undertaken using several tests. One of the most commonly used tests is the R^2, which is the ratio between the explained sum of squares and the total sum of squares. The result gives a percentage of how well the model explain the variation in the dependent variable. If R^2 is 0.5 then the model can explain 50 % of the variation in the dependent variable. The model cannot explain the remaining 50 %. But it has to be kept in mind that the R^2 will increase when an additional independent variable is included in the model. So it is also good to look at the adjusted R^2 that takes the number of variables in mind. The adjusted R^2 increases only if the new variable can explain something in the model that couldn't be explained before (Stock and Watson, 2012).

A White's test is one of the most commonly used to test for heteroskedasticity, which is the case when the residual error term varies differently when a variable increases. A test doesn't really say that the model suffers from heteroskedasticity but it's a signal that something in the model might be wrong. Cross-sectional data are more likely than other forms to suffer from heteroskedasticity. A White's test uses the squared residuals to test the hypothesis of heteroskedasticity. The test statistic that is used is called chi-square test. In this test the sample size, N, is multiplied with the unadjusted R^2 (when squared residuals are used as dependent variable). That value is called the langrange multiplier, LM. If the calculated value of $N*R^2$ is higher than the chosen chi-squared value then the hypothesis that heteroskedasticity are present cannot be rejected (Studenmund, 2006).

Models can also be suffering from multicollinearity, when explanatory variables are strongly correlated to each other. The variance inflation factor, VIF, test can give an indication if that is the case. A VIF is obtained for each explanatory variable. When VIF is over five it is a sign that multicollinearity is present (Studenmund, 2006).

To test if several coefficients do not belong in the model a F-test can be done. The F-test makes it possible to test if one or several coefficients are not different from zero. If that is the case they might not belong in the model. The null hypothesis is set as that one or several coefficients are zero. The F-test is based on the sum of squared residuals from two version of the model. The restricted regression is the one where the null hypothesis is true, in this model the coefficients are set to zero and the variables are excluded. In the unrestricted model all variables and coefficients are included (Stock and Watson 2012).

$$F = \frac{(SSR_{restricted} - SSR_{unrestricted})/q}{SSR_{unrestricted}/(n - k_{unrestricted} - 1)}$$

In the formula the $SSR_{restricted}$ is the sum of squared residuals in the model where the variables with coefficient that could be zero are excluded. The $SSR_{unrestricted}$ is the sum of squared residuals in the model where all variables are included. Q stands for number of restrictions. N stands for the number of observations and $k_{unrestricted}$ is the number of variables included in the unrestricted model (Stock and Watson).

The F-value calculated has to be compared to a critical value that depends on a significance level chosen and degrees of freedom in the nominator and denominator. If the F-value calculated is equal or larger than the critical value than the null hypothesis can be rejected (Stock and Watson, 2012).

4. Data and area description

This section contains a data description where the data set is presented with information on delimitation, time period and an explanation on how the prices can be compared despite inflation over the observed time period. The area description describes what kind of area the observations are located in. Mean prices of houses in the area in the given time period 2009-2013 is presented. Some short information on education level and other circumstances in the area are provided in the section aswell. Under this section the variables included in the study are presented aswell. How they are stated and summary statistics are provided.

4.1. Data

Data that will be used for the analysis is the selling price and attributes for houses, both residential and summer houses, within a range of 25 kilometres from Forsmark nuclear power plant. The maximum distance was chosen mainly because of geographically reasons and time limitation. 25 kilometres was a good distance that would not split any town into two parts. Within 25 kilometres household belongs to the municipality of Tierp in the north and the municipality of Östhammar in the other directions.

Observations with missing values on some variable were excluded from the set. The number of observations was finally 413. Houses sold from January 2009 until December 2013 was included in the data set to get an acceptable time period before and after the Fukushima accident.

Data was collected from the company Booli, which publish prices of sold objects and the other variable values except distance, on their homepage. The numbers comes from the registration of house title that has to be done in connection to the sale, which shows that the property has changed owner. Distance was calculated using Daft logic, a distance calculator on the Internet.

The selling prices have been adjusted so the monetary value is in 2009 SEK. Using CPI, consumer price index, adjusted house prices were calculated.

Table 2, Consumer price index 2009-2013

	2009	2010	2011	2012	2013
CPI	299.6600	303.4600	311.4300	314.2000	314.0600
Adjusted CPI	1.0000	1.01268	1.03928	1.04852	1.04805

(SCB, 2014)

The adjusted CPI is calculated by dividing each years CPI with the CPI from 2009. Then all prices are divided with the adjusted CPI for the year the house was sold in. Then house prices can be compared with each other.

4.2. Area description

Forsmark nuclear power plant is located in the municipality of Östhammar. Geographically it’s located on the coast of Sweden 140 kilometres northeast of the capital of Sweden. The surrounding area is divided into two different municipalities, Tierp and Östhammar. In figure 1 an overview over the area is presented. Forsmark is marked with a yellow nuclear sign in the upper right corner.

In the municipality of Östhammar the main city is Östhammar. They have a quite stable population over 21 000. The most common employers in the area are within health and social care, manufacturing and mining, and energy and environment (SCB, 2013).

Figure 1, Map over the area

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In the area of municipality of Östhammar there is a lower rate of postsecondary education in the population than in the county and overall in Sweden. The municipality has a net commuting that is negative, meaning that there is a bigger amount commuting to other areas than into Östhammar from other areas (SCB, 2013).

As for the municipality of Tierp the most common employers are in the areas of manufacturing and mining, and health and social care. Like Östhammar also Tierp has a net commuting that is negative, where Uppsala is the most common place to commute to (SCB 2012).

A part of the circle of 25 kilometres around Forsmark nuclear power plant is the Baltic Sea, as seen in figure 2. The circle represents a 25 kilometres range around Forsmark, however it is not in scale.

Figure 2, 25 kilometres around Forsmark

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To have a reference point in the analysis a mean value of sold houses each year are described in table 3.

Table 3, Mean house prices in the area

	2009	2010	2011	2012	2013
Municipality of Tierp					
Permanently single-family houses	986000	984000	1012000	1056000	987000
Summer-houses	803000	880000	683000	897000	788000
Municipality of Östhammar					
Permanently single-family houses	1344000	1367000	1485000	1420000	1359000
Summer-houses	1136000	1367000	1255000	1271000	1414000
Mean price	1067250	1149500	1108750	116100	1137000

(SCB, 2014 (2))

For the municipality of Tierp it is interesting to see that summerhouses had a price dip in 2011. Interestingly for permanently single-family houses in the municipality of Östhammar prices was highest in 2011.

The area of 25 kilometers around Forsmark nuclear power plant is mostly rural with some urban areas such as Östhammar and Öregrund.

4.3. Variables in the model

The specified model will have house prices as the dependent variable; house prices will be the actual selling price of the house adjusted for inflation. Price will be converted to logarithmic form. The logarithmic form is the most common in this kind of analyses.

The independent variables included in the analysis are the following ones. Number of rooms, living area, other area (such as basement, indoor garage etc.), lot size, year of construction, year of selling and distance to Forsmark nuclear power plant. Summary statistics of the independent variables are described in table 4.

Some independent variables do not have a linear relation to the dependent and then either logarithmic form or polynomial form can be used. The distance variable can be assumed to have a non-linear effect on price. Adding a squared distance variable into the model will capture that. Also the living area will be included as a non-linear variable in quadratic form.

Distance to Forsmark nuclear power plant was calculated using Daft Logic, a distance calculator on Internet. The distance was calculated as a straight line. A straight line was chosen since the risk of being near Forsmark is the distance measured straight from the points and not the distance to drive for example.

The dummy variable Y09, houses sold in 2009, will be excluded from the model in order to avoid the dummy variable trap, and therefore avoid perfect multicollinearity. Y09 was chosen since it is better to have two years after 2011 (year of Fukushima accident) so that a possible Fukushima effect will be easier to identify.

In table 4 summary statistic for all included variables are presented.

Table 4, Summary statistic

Variable	Definition	Mean	Median	Minimum	Maximum
l_Adjusted_Price	Log of price adjusted into 2009 value	13.897	13.898	12.208	16.338
Adjusted_Price	Price adjusted into 2009 value	1276000	1086200	200370	12461000
Rooms	Number of rooms	4.1562	4	1	10
Livingarea	Living area in square metres	99.367	95	18	699
Sq_Livingarea	Squared living area in square metres	12758	9025	324	488600
Otherarea	Other area in square metre	33.987	15	0	220
Lotz	Lot size in square metre	3007.1	1942	314	64000
Buildyear	Year of building	1956.6	1968	1800	2008
Y09	Houses sold in 2009=1, otherwise=0	0.14528	0	0	1
Y10	Houses sold in 2010=1, otherwise=0	0.19855	0	0	1
Y11	Houses sold in 2011=1, otherwise=0	0.24213	0	0	1
Y12	Houses sold in 2012=1, otherwise=0	0.23002	0	0	1
Y13	Houses sold in 2013=1, otherwise=0	0.18402	0	0	1
Dist	Distance to Forsmark nuclear power plant in kilometres	18.068	18.495	3.2	24.99
sq_Dist	Distance to Forsmark nuclear power plant in square kilometres	345.7	342.07	10.24	624.5

5. Econometric results

This section contains the econometric result from the model estimated with Gretl. All variables are presented with the estimated coefficients and t-ratios and p-values. After that an examination of the results from the modelling follows. The results from the tests that were made are presented aswell as an interpretation of the implicit prices and last an in-depth analysis of distance effect of house prices conclude the econometric results.

5.1. Model

The model was estimated with OLS-regression using the software Gretl. The result of the regression is summarized in table 5. The numbers in table 5 will be analysed in the section analysis of the model. The model was estimated with robust standard errors.

The model is in semi-log form, the dependent variable, price, is the only one set in logarithmic form in this model.

Table 5 OLS-regression with L_Adjusted_Price as dependent variable

Variable	Coefficent	standard error	T-ratio	P-value	Significance
Constant	8.90885	1.60710	5.543	5.39e-08	***
Dist	0.104694	0.0276741	3.783	0.0002	***
sq_Dist	-0.00309286	0.000865046	-3.575	0.0004	***
Y10	0.0380381	0.0774366	0.4912	0.6235	
Y11	−0.0196749	0.0702999	−0.2799	0.7797	
Y12	0.109785	0.0670882	1.636	0.1025	
Y13	−0.000717303	0.0795822	−0.009013	0.9928	
Rooms	0.0693644	0.0263326	2.634	0.0088	***
Livingarea	0.00579266	0.00123224	4.701	3.57e-06	***
sq_Livingarea	-5.98852e-06	1.56992e-06	-3.815	0.0002	***
Otherarea	-0.00119862	0.000563042	-2.129	0.0339	**
Lotz	-6.15165e-06	3.51299e-06	-1.751	0.0807	*
Buildyear	0.00174269	0.000841603	2.071	0.0390	**

* Significant at 90 %, ** Significant at a 95 % level, *** Significant at a 99 % level, R^2= 0.29072, Adjusted R^2=0.26944, N=413

$$l_{adjustedPrice} = \beta_0 + \beta_1 * Dist + \beta_2 * sq_{Dist} + \beta_3 * Y10 + \beta_4 * Y11 + \beta_5 * Y12 + \beta_6 * Y13 + \beta_7 * Rooms + \beta_8 * Livingarea + \beta_9 * sq_{Livingarea} + \beta_{10} * Otherarea + \beta_{11} * Lotz + \beta_{12} * Buildyear$$

In table 6 the mean implicit prices are calculated at the sample mean. Each variables coefficient is multiplied with the mean of adjusted_price (1276000 SEK). Except for the implicit price of livingarea and distance, which were calculated as

$$Implicit\ price_{livingarea} = Price_{mean} * (\beta_{Livingarea} + 2 * \beta_{sq_{Livingarea}} * Livingarea_{mean})$$

$$Implicit\ price_{dist} = Price_{mean} * (\beta_{dist} + 2 * \beta_{sq_{dist}} * Dist_{mean})$$

Not that the implicit price here is not in logarithmic form (see theory section).

Table 6, Implicit mean price

Variable	Coefficent	Implicit price
Dist	0.1047	-9020.8
sq_Dist	-0.0031	
Y10	0.0380	48536.62
Y11	-0.0197	-25105.17
Y12	0.1098	140085.66
Y13	-0.0007	-915.28
Rooms	0.0694	88508.97
Livingarea	0.0058	5872.84
sq_Livingarea	0.0000	
Otherarea	-0.0012	-1529.44
Lotz	0.0000	-7.85
Buildyear	0.0017	2223.67

5.2. Analysis of the model

In this section a discussion about the model and an interpretation of each estimated coefficient will be presented. A presentation of the result of the White's test that was made on the model will follow as well. The VIF was calculated for all explanatory variables. A F-test was also made to see if the selling year variables could be excluded.

5.2.1. Econometric credibility

In the model described in table 4 the R^2 has a value of 0.291. That can also be read as that the model can explain about 29 % of the variation in the logarithmic of house prices in the area during the time period studied. Compared to the papers referred to in the introduction this is a quite low number. Although that was expected since the number of explanatory variables was lower in this model. The adjusted R^2 is 0.269. Which implies that when adjusted for number of variables the explanation of variation in price is around 27 %.

For the model a White's test was made to see if there was a case of heteroskedasticity. The result of the null hypotheses (that heteroskedasticity is not present) was a Lagrange multiplier, LM, of 64.9135 and a p-value of 0.855. The chi-squared value is set to 78, which is more than the calculated LM value. The null hypotheses can be rejected if the calculated value of LM is larger than the chi-squared value. In this case it is not larger and therefore the null hypothesis of no heteroskedasticity cannot be rejected. The null hypotheses can also be refered to as that there is homoscedasticity, that the variance of the error term is constant. Which is the coveted and if the null hypotheses cannot be rejected it is a satisfying result.

In table 7 the values of the VIF analyse is shown. A value larger than 5 often is used as an indicator for multicollinearity (Studenmund, 2006). The variables that have a higher value than 5 are distance, squared distance and living area. Since these are the same values only that one variable is the others squared version that is not really a problem. So it is quite safe to say that the model doesn’t suffer from multicollinearity.

Table 7, VIF

Variable	VIF
Dist	35.407
sq_Dist	34.978
Y10	1.922
Y11	2.088
Y12	2.021
Y13	1.920
Rooms	2.497
Livingarea	7.439
Sq_Livingarea	4.751
Otherarea	1.216
lotz	1.143
Buildyear	1.110

5.2.2. Estimated coefficients

For the coefficients calculated there are some expected results and some not so expected. First of all the constant/intercept is quite high and significant at a very high level. The intercept tell us what the value of the dependent variable is when all the independent variables are equal to zero.

The dummy variables for selling years are all insignificant. So the estimated coefficients for these variables have to be interpreted with caution. Any conclusions drawn from this result have to be presented with the awareness of its uncertainty. This being said, for houses sold in

2011 and 2013 the estimated coefficients are negative, meaning that prices are affected negatively if the house was sold in either of these years. Both of these coefficients are highly insignificant. For 2010 and 2012 the estimated coefficent are positive, which gives a positive affect of the price if houses were sold in these years. For 2012 the p-value is the lowest for all selling year variable with a value of 0.1025. This is also the year with the highest value of the coefficient, with a value of 0.11. This means that price increase with 11 % if the house is sold in 2012.

Since all dummy variables for selling year were insignificant a F-test was made. In this case the formula for the F-test looked like

$$1.04 = \frac{(93.5 - 92.5)/4}{92.5/(413 - 13)}$$

With a significance level of 5 % the corresponding critical value would be 2.37. Since the critical value is larger than the computed value the null hypothesis cannot be rejected. This implies that the coefficients for which year the house was sold in are not different from zero and therefore maybe dosen't belong in the model. This is an interesting result since the possible Fukushima effect should have been seen in the variable of 2011. However the coefficient for 2011 did turn out negative as foreseen but it's not significant and the F-test showed that it might not even belongs in the model. Therefore the Fukushima effect is not found in this data set.

The number of rooms has a coefficient of 0.07, which is significant. This means that price increases by 7 % when an extra room is added, when everything else is held constant. In other papers such as Clark and Alison (1999) and Clark and Nieves (1994) number of bedrooms is used as a similar variable. Clark and Alison (1999) found a negative impact (although it was insignificant) while Clark and Nieves (1994) found a positive and significant impact. The implicit price for number of rooms is 88509 SEK at mean price, which is not a constant. Since the coefficient correspond to a price in logarithmic form the change in price is in percentage.

Living area has a coefficient of 0.006, which is statistically significant. The squared living area is also significant and has a value of -0.000006. This is in line with the finding of Clark and Alison (1999), which had a coefficient of 0.0004 that also was significant. At mean price and the other variables set constant the implicit price of living area is 5873 SEK. This corresponds to 0.5 % of the mean price. However this is not a constant percentage since the living area is included in quadratic form and changes when living area changes.

The variable other area had a value of -0.001. The value is significant. The implicit price for other area is negative. Which means that when other area increases price decreases. For an additional square metre of other area the price would go down with 1529 SEK from mean price. Which in percentage would be - 0.12 %.

The size of the lot, the variable lotz, has according to the model a negative impact on price. It is significant at a 90 % level. The negative sign of the coefficient of lot size is quite surprisingly compared to recent studies that showed a positive impact, (Clark et. al. 1997), (Clark and Alison 1999). It could be caused by a wide distribution of the observations in this variable. The implicit price is – 8 SEK. An additional square metre in lot size gives a decrease by 8 SEK from mean price. The percentage influence of lot size is - 0.0006 %. This can be considered as a very low number but then it is good to keep in mind that lot size probably differ more than one square metre between houses. If for example then it differ 100 square metres between two otherwise identical houses the price difference would instead be 0.006 %.

Year of construction, the variable buildyear, has a coefficient of 0.002, and it is significant. In Clark et. al. (1997) they instead of using the year of building used the age of the house. Age of house had a negative impact, which is in line with the positive coefficient in this paper that says that a house build more recently is more expensive than an older house. The implicit price of the variable buildyear is 2224 SEK. When everything else held constant the price difference between two houses that was built with a difference of one year at mean price the difference in price would be 2224 SEK in favour of the more recent built house. The year of construction correspond to a 0.17 % of the price.

Somethings that has to be kept in mind when looking at the implicit prices are that these values presented here are calculated at the mean value of price. Since price is a part of the formula for implicit price, the implicit price presented here is not constant. So the implicit price is dependent on the price of the house.

Another thing that has to be kept in mind is that the implicit price has to be in contrast to what the variable stands for. For example Y12 can only be zero or one. Lot size that has the smallest value of implicit price also is the variable with the largest variation and range in the variable. The difference between two houses might not be one square metre in lot size in fact rather it can be 1000 square metre. Therefore the implicit price for a one unit change can be quite small but in fact the real value between houses are bigger.

5.2.3 . Distance

As for the distance variable it has to be interpreted in a two-stage way. The coefficient of distance is 0.105 and significant; this means that when distance increases with one kilometre the price increases with 10.5 %. But the distance variable is also included in squared form, which makes it a bit more complicated. It means that price will not increase with 10.5 % for each extra kilometre to eternity. The price is increasing at a decreasing rate when distance is increasing, that is because the coefficient for Dist is positive and for sq_Dist is negative.

To get a clearer view and to understand how distance affect prices, further analyses were made. For further analyses of distances affect on prices a table was made to see how the price changes when distance vary and everything else is held constant. To do this every calculated coefficient in table 4 was multiplied with the mean value of that variable and then summed up with the intercept.

$$const + \beta_{y10} * Y10_{mean} + \beta_{y11} * Y11_{mean} + \beta_{y12} * Y12_{mean} + \beta_{y13} * Y13_{mean} + \beta_{rooms} * Rooms_{mean} + \beta_{Livingarea} * Livingarea_{mean} + \beta_{sq_{Livingarea}} * sq_{Livingarea_{mean}} + \beta_{otherarea} * Otherarea_{mean} + \beta_{lotz} * Lotz_{mean} + \beta_{buildyear} * Buildyear_{mean} = 13.07476$$

The calculated value was then used as the new intercept of the equation; the new intercept is the same as log of price when distance is equal to zero. Then distance was allowed to vary from 0 to 30 kilometres. A limit of 30 kilometres was set to see what happens after the maximum of 25 kilometres in the data set is reach. Although it has to be kept in mind that everything after 25 kilometres are rough estimates from the calculated values using 0 to 25 kilometres as distance. The calculated values of log of adjusted price when distance varies from 0 to 30 kilometres are presented in table 8. In the table the log of adjusted price was calculated as following:

$$L_{Adjusted\,Price} = 13.07476 + 0.104694 * Dist - 0.00309286 \times Dist^2$$

Except from the log of price the actual price and the implicit price were calculated for each kilometre aswell. This result is also presented in table 8. The actual prices were calculated by antilog the log of prices. The implicit prices were calculated by using the partial derivative of log of price with respect to distance.

Table 8 Log of price, price and implicit price when distance vary from 0-30 kilometres

Distance in kilometres	Log of price	Price	Implicit price
0	13.07	476755.95	49913.49
1	13.18	527741.12	51986.83
2	13.27	580576.33	53600.20
3	13.36	634762.54	54676.29
4	13.44	689726.38	55144.18
5	13.52	744827.93	54942.23
6	13.59	799371.47	54020.88
7	13.66	852618.82	52345.17
8	13.71	903805.05	49896.91
9	13.77	952156.17	46676.41
10	13.81	996908.23	42703.56
11	13.85	1037327.18	38018.25
12	13.89	1072728.71	32680.04
13	13.91	1102497.55	26767.10
14	13.93	1126105.12	20374.39
15	13.95	1143125.23	13611.19
16	13.96	1153246.82	6597.96
17	13.96	1156283.41	-537.21
18	13.96	1152178.85	-7662.45
19	13.95	1141009.03	-14646.22
20	13.93	1122979.52	-21361.32
21	13.91	1098419.34	-27688.74
22	13.88	1067770.9	-33521.17
23	13.85	1031576.8	-38766.04
24	13.81	990463.84	-43347.85
25	13.76	945125.03	-47209.94
26	13.71	896300.16	-50315.42
27	13.65	844755.96	-52647.39
28	13.58	791266.23	-54208.38
29	13.51	736592.97	-55019.22
30	13.43	681468.97	-55117.21

Implicit price for distance was calculated as:

$$Implicit\ price = price * (\beta_{dist} + 2 * \beta_{sq_{dist}} * dist)$$

In figure 3 implicit prices when distance increases are presented. Figure 4 describes the change in price when distance increases.

Figure 3 Implicit prices when distance vary from 0 to 30 kilometres

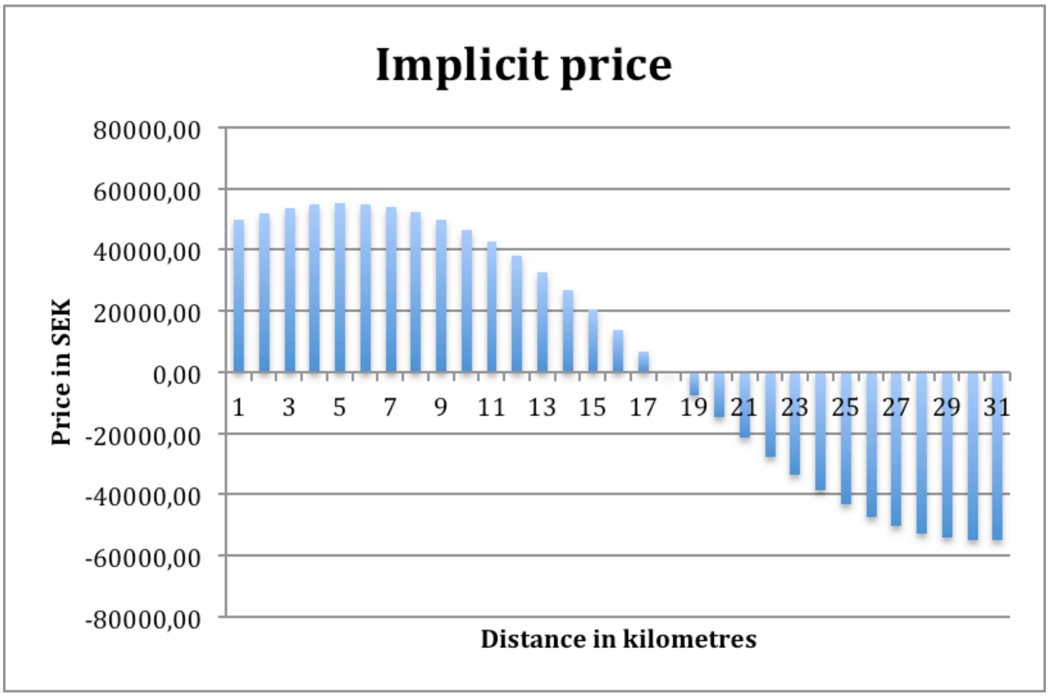
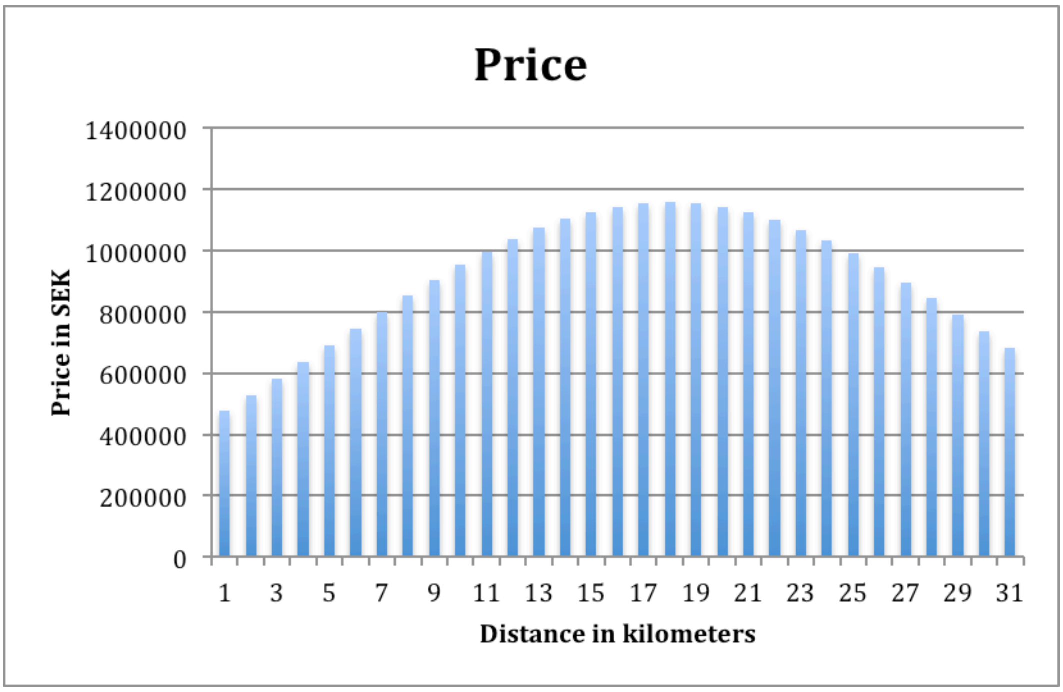


Figure 4, Price when distance varies from 0 to 30 kilometres



The implicit curve shows the slope of the price curve in figure 4. In figure 3 the implicit prices are shown when distance increase from 0 to 30 kilometres. The implicit price is the derivative of the log of the prices shown in figure 4. The implicit price is the slope of the price curve. So when the price curve reaches the maximum point the implicit price goes from positive to negative. Meaning that consumers are not willing to give up other goods to pay extra for an additional kilometer. After this point an extra kilometer does not increase the house price.

Looking at the implicit prices the rate of how prices are affected by the increasing distance can be seen. The marginal willingness to pay for an extra kilometer is increasing for every extra kilometer added up to around 7 kilometers and then the marginal willingness to pay for an extra kilometer is decreasing. From around 17 kilometers consumers are not willing to pay extra for an additional kilometer.

6. Discussion and concluding remarks

Overall the model can be considered as quite reliable with significant coefficients and a satisfying R^2 (and adjusted R^2), considering the number of explanatory variables, the number of observations etc. However compared to previous studies the R^2 is low. The model and the explanations degree could be improved and some thoughts on how to improve the model will follow in this section. But first let us recall the research question.

The research questions stated in the introduction was:

1. Will house prices increase when distance to Forsmark increases?
2. Does the Fukushima accident in 2011 affect house prices within 25 kilometres of Forsmark?

The hypothesis for the first question was that a positive relation between distance and prices would be found. This was also the case, the model found an increase in price at a decreasing rate when distance increased. So a negative nuclear power plant effect was found. However this effect is not constant and not at all values of distance. House prices increased when distance increased to a distances of around 17 kilometers. After that distance seems to have no influence on house prices.

Unlike Clark et. al. (1997) the relation of distance and house prices in this study was a reversed U-shaped curve. This is an interesting point and could be caused of different opinions of the population in Sweden and the United States. Maybe Clark et. al. (1997) saw an effect of higher prices close to the plant that was caused by employees that valued closeness to the workplace. Why that didn't happen in this study could for example be that workers at Forsmark nuclear power plant do not value closeness to the same extent or that there are fewer workers at Forsmark in comparison to those with other employers in the area.

The result is interesting and can be used for making decision regarding location for nuclear power plants. It is also interesting in the debate of the existence of nuclear power plant. Although to use this kind of analyses to make large decisions a larger scale and data set would be preferable.

As for the second question no statistically significant result of a Fukushima effect could be found. Although a negative coefficient was estimated for 2011, it was statistically insignificant and therefore has to be interpreted with care. So, there is a Fukushima effect with negative implicit prices for 2011 but it is not safe to say that this result didn't occur by chance.

Why a statistically significant Fukushima effect was not found can depend on several things. Maybe the population in the area has a strong faith in the security at Forsmark. It could also be an indication that since the accident was caused by a natural disaster it had a lower impact in Sweden since Sweden is quite spared from natural disasters.

Another possibility for why a Fukushima effect couldn't get determined could be that the model wasn't able to capture such an effect. For this question other methods might be better to use. In this case maybe Contigent Valuation Method, CVM, would be better to use to capture a Fukushima effect. However results from CVM often is an overestimation of the populations' willingness to pay for an amenity. But to find a possible Fukushima effect CVM might have been a better method.

As for the first question the Hedonic price model can be consider as a good method. It gives a more straightforward result than CVM. The method also answered the first research question.

However a model can always be improved. A way to improve the model would be to use more variables. Variables that could be good to include is number of bathrooms, distance to nearest city, school and the Baltic Sea. Since this is an area with a lot of summer houses the distance to the Baltic Sea could probably explain some variations in the prices that the other variables do not capture to the same extend. This study lacked neighbourhood variables overall which probably would give a higher grade of explanations of the price variations.

The main difference between this study and recent studies are the number of independent variables and especially the surrounding variables such as distance to a nearby city, or different public services (as schools, transportation). Also number of observations and number of years included were less in this analysis compared with other, recent studies. All this is reflected in the adjusted $R^{2,}$ which in this study was lower than the ones discussed in the introduction section. Although this study has a lower degree of explanation it can still describe almost 30 % of the variation in the prices.

Another way to extend the research would be to compare the three nuclear power plants in Sweden with each other to see if there are different views on nuclear at different places in Sweden.

Increasing the distance would be interesting as well, since for example Yamane et. al. (2013) used a distance up to 80 kilometres from the nuclear power plant. This would also include Uppsala, which has a distance in a straight line of 64 kilometres to Forsmark.

It would be interesting to capture both income and if the owner of the house works at the power plant or not. Studies have shown that those who work at a nuclear power plant perceive a lower risk than others. That could maybe capture an effect such as the one seen in Clark et. al. (1997).

Since Clark and Allison (1999) found a connection between nuclear waste storage and house prices it would be interesting to look closer into that in Sweden too, especially since the plans of building a final disposal facility at Forsmark.

The public opinion of nuclear power has had a negative trend the last couple of years an extended version of this study would be interesting. To include public opinion and media coverage in the calculations would be interesting.

The distance variable may be read wrong. Many of the houses included in the data set are placed in the town of Östhammar. The distance variable may capture a reverse effect of that, meaning that a positive connection between house prices and distance may be a reflection of a negative connection between house prices and distance to Östhammar. But distance to Östhammar from Forsmark is almost 19 kilometres in contrast to almost 17 for distance in this study so maybe that is not the case. With or without this scenario it would be good to include variables that capture distance to a near urban area.

For further research some adjustments should be done such as include more independent variables, observations, increase the distance and number of years and maybe also the other nuclear power plants in Sweden.

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