The influence of solar farms on residential property values

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Abstract

The number of solar farms in the Netherlands grows exponentially, however, they possibly also cause negative externalities for local residents. This paper examines the effect of solar farms on residential property values. I disentangle the effect by investigating the anticipation effect between permit and opening and the effect after opening by using a difference-in-difference hedonic model. I use residential property transaction data from 2015 to 2022 from the Netherlands. My results indicate that residential properties located within 1 kilometer from a solar farm, decrease in value with 2.85% after the opening of the solar farm. I find a smaller decrease in the anticipation period between the license and opening date, however this effect is not significant. Furthermore, I find that the negative effect is stronger in urban regions and with properties constructed after 2000. In conclusion, my findings indicate that building solar farms in the proximity of residential properties results in a significant loss in residential property values.

Keywords: solar farms, residential property prices, residential real estate, infrastructure, energy

Colophon

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1 Introduction

The use of fossil fuels and non-renewable energy is getting more debated in the Netherlands, while the use of renewable energy increases every year in the Netherlands. According to the Dutch national statistical agency, CBS (Linders et al. 2021), the percentage of renewable energy used in the Netherlands grew from 1.6% in 2000 to 11.1% in 2020 and the Dutch government agreed with the European Union to increase this percentage to 27% in 2030. Therefore, it is necessary to further increase the capacity to generate renewable energy in the coming decade.

In 2020, 14% of the generated renewable energy was solar energy in the Netherlands. Most renewable energy is generated with biomass and wind energy. However, solar energy is the renewable energy type with the strongest growth. Between 2010 and 2020, the capacity to generate power from solar panels in the Netherlands grew from 90MW to 10.717MW. This capacity growth is the result of consumers adding solar panels to their houses and companies building large solar farms. Especially the construction of solar farms became popular in the last decade. Between 2015 and 2020 the number of solar farms in the Netherlands increased from 6 to 272, with exponential growth each year (RVO, 2021). This fast increase of the number of solar farms in the Netherlands is interesting, as the Netherlands is one of the most densely populated countries in the world (World Population Review, 2022). Therefore, most solar farms are built in the vicinity of residential areas and possibly affect the values of relatively many the residential properties in the proximity. If the residential property values are affected, this should be considered in the planning process of future solar farms. In addition to the dense population, the Netherlands is also an interesting sample, as it is one of the most climate-aware countries in the world, with a climate awareness among its population of 95.6% in 2015 (Lee et al. 2015). As contributing to emission reduction and taking environmentally friendly actions, which are correlated with being climate aware, are perceived as positive (Andreoni 1990; Ma and Burton 2016), it is interesting to research whether this also indicates that solar farms are perceived as a positive externality and increase neighboring house prices in the Netherlands, or that the negative characteristics outweigh the possible positive characteristics. The climate awareness and efforts to reduce your energy footprint became even more relevant as a result of the recent energy crisis caused by the sanctions following the war between Russia and Ukraine. This caused the energy prices in the Netherlands to increase immensely. Before the war, in 2021, the average energy price was €43.06 per KWH. In 2022, this increased to an average of €91.50 per KWH with a value of approximately €300 per KWH in October 2022, the last researched month of my sample (CBS, 2022). This increase in energy prices is mainly caused by increased gas prices, which account for 44% of the electricity production in the Netherlands. This dependency on expensive gas increased the demand for solar panels in the Netherlands (RTL nieuws, 2022).

Solar farms provide green energy which is widely considered as positive. However, the growth in solar energy capacity might not only have positive effects, as renewable energy-generating facilities often generate negative externalities (Droes & Koster, 2016; Möllendorff & Welsch, 2017; Gaur & Lang, 2020). Wind turbines for example, are notorious for polluting the horizon and generating noise. In addition, solar panels are not perceived by most as visually pleasing and they reflect sunlight which negatively affects surrounding inhabitants (Droes & Koster, 2021). According to theory, these negative externalities should affect house prices (Rosen, 1974) and in line with this theory, the negative effect of wind turbines on housing prices is already extensively proven (e.g. Jensen et al., 2014; Gibbons, 2015; Droes & Koster, 2016). However, whether a negative effect of solar farms on housing prices is present as well, is not widely researched and still debated.

In the limited existing literature regarding the effect of solar farms on housing prices, several concerns were found among local communities regarding the opening of nearby solar farms. Concerns of local communities include the land use intensity, the reliability of the sun as a power source, the transmission of solar power, esthetic concerns, water usage and property value reduction (Farhar et al. 2010; Gross, 2020). In addition, the construction of solar farms also has a negative effect on the ecosystem and wildlife in the area (Lovich & Ennen, 2011; Knegt et al. 2021). However, the externalities of solar farms are not only negative. Both local and non-local residents emphasize the social, economic and environmental benefits and in addition, local residents value the economic benefits even more than the non-local residents (Farhar et al. 2010).

Whether the externalities of the construction and opening of solar farms on nearby house prices are positive or negative for local residents is not widely researched yet. However, the available papers mainly indicate a negative correlation between the opening of a solar farm and the relative value of nearby house prices (Gaur & Lang, 2020; Droes & Koster, 2021; Maddison et al., 2022). They argue that the negative externalities outweigh the benefits of a solar farm for local residents. However, contrary to these findings, Lang et al. (2021) find that these negative externalities do not always outweigh the benefits. They state that it depends on the prior use of the site and the visibility of the solar farm, whether the solar farm is seen as a positive or negative amenity by local residents. They find that local residents are willing to pay a premium to turn commercial, industrial or brownfield sites into solar farms and in addition, local residents also value solar farms as a positive amenity and would like to pay a premium if the solar farm is not visible. However, they also find that local residents are also willing to pay to prevent solar farm development if the location was previously a farm or forest.

In the currently available literature, the effect of solar farm development on residential property prices is still debated. Therefore, this paper contributes to the existing literature by discussing the effect of solar farm establishment on residential property prices in the Netherlands. In addition, a possible effect of a solar farm on residential properties in the proximity is not limited to an effect after the opening of the solar farm. Kiel and McClain (1995) suggest that negative externalities associated with the construction of an energy-generating facility are partly factored into neighboring residential property prices prior to its opening. Therefore, a possible effect might be priced in before the opening of the solar farm. In line with this theory, Figure 1 in Appendix A suggests that an anticipation effect might exist before the opening of a solar farm. To the best of my knowledge, this paper is among the first to investigate the possible anticipation effect of solar farms. Jarvis (2021) includes an anticipation period, however, he does not find a significant effect. Therefore, by including an anticipation period, this paper contributes to the existing literature.

The aim of this research is to quantify the externalities of solar farms in the Netherlands and measure whether local residents perceive the solar farm as a negative or positive externality by doing a hedonic difference-in-difference analysis. I use a target area of 1 kilometer around the solar farm and a control area between 1 and 2 kilometer. The sample size consists of five solar farms and 3,741 residential property transactions. My results indicate that residential properties located within 1 kilometer from a solar farm, decrease in value with 2.85% after the opening of the solar farm. I find a smaller decrease in the anticipation period between the license and opening date, however this effect is not significant. Furthermore, I find that the negative effect is stronger in urban regions and with properties constructed after 2000.

The remainder of this paper is structured as follows. The following section is the literature review. Section 3 and 4 will describe the chosen methodology and data respectively. In section 5 the results will be presented and discussed. In section 6 an alternative specification and heterogeneity test will be presented and discussed. In section 7 conclusions and limitations will be given.

2 Literature review

In recent years, there has been a growing interest in examining the impact of renewable energy developments on the prices of residential properties. However, as solar farms on a large scale are a relatively recent development, research on the effect of these solar farms on housing prices is still limited and the effect of solar farms on residential property values is still debated. Gaur & Lang (2020), Droes & Koster (2021), Jarvis (2021) and Maddison et al (2022), researched the effect of solar farms on residential property values. Gaur & Lang (2020), observed more than 400,000 residential transactions within three miles of 208 solar farms in Massachusetts and Rhode Island between 2005 and 2019. They find that residential property values decrease by 1.7% within one mile of the solar farm after opening. Droes & Koster (2021) researched the effects of solar farms and wind turbines on housing prices in the Netherlands. They researched the effect 107 solar farms had on housing prices after the opening of the solar farm. They use 12,650 transactions within one kilometer of the solar farms between 2009 and 2019. They find that solar farms indeed negatively affect housing prices within 1 kilometer by 2.6%. Jarvis (2021), used a sample of 1,675 solar farm projects in the United Kingdom to research the effect on residential property values. He uses transactions in England and Wales since 1995. He finds no significant correlation between the development and opening of solar farms and residential property values. He argues that the absence of a significant negative effect is caused by high approval ratings and low risks of misallocated investment. These results are in contrast with Maddison et al. (2022). They researched the effect of the opening of 1,059 solar farms in England and Wales. However, they find that residential properties within 750 meter, suffer from a significant 5.4% reduction in prices after the opening of solar farms. However, they state that this only applies if the solar farm is larger than 5MW and only if it is not located to the south of the residential properties. This further specification might explain the difference between the outcomes of Maddison et al. (2022) and Jarvis (2021), despite using a similar sample.

In addition to the existing hedonic literature on this subject, Lang et al. (2021), conducted a survey among 3,000 residents in Rhode Island about their opinions regarding solar farm developments near residential areas. They find that the prior usage of the land the solar farm is located, is a very important indicator of approval by local residents. They find that residents are willing to pay a premium if the solar is located on a former commercial, industrial or brownfield site or when the solar farm is not visible. However, they also state that residents would also like to pay a premium to avoid developments on farm and forest lands. According to the hedonic pricing model by Rosen (1974), this can be explained by the fact that negative characteristics are removed and/or positive characteristics are added. However, a weakness of this research compared to the hedonic research on this topic, is that not the actual effect of a solar farm on residential property prices is measured. In the survey, they measure how local residents think they would react and not how they actually reacted. The actual reaction is measured in the existing hedonic research, as it measures the actual residential property price changes post opening of the solar farms. Therefore, in line with the existing hedonic literature, I hypothesize that the opening of a solar farm will negatively affect nearby residential property prices. I argue that the solar farms in the Netherlands are viewed as a negative externality based on prior research by (Gaur & Lang, 2020; Droes & Koster, 2021; Maddison et al., 2022), as they all found a negative correlation between solar farms and residential property values.

Most existing literature describes the effect post opening of a solar farm. Literature including the anticipation effect of solar farm developments on residential property values is limited. Kiel & McClain (1995) however, state that an anticipation effect does exist. They find that in the period predating the opening of an energy-generating facility, a significant negative effect on surrounding residential property prices is present. They argue that before and during the construction, people already anticipate future negative externalities and therefore, it is already reflected in the residential property prices before the actual opening of a development. To the best of my knowledge, the sole study that has incorporated an anticipation period into an examination of the impact of solar farms on the values of residential properties, is Jarvis (2021). However, he did not find a significant anticipation effect. This is in contrast with Figure 1 in Appendix A, which suggests that an anticipation effect might exist before the opening of a solar farm. Based on this, I hypothesize that between the permit date and the opening of the solar farm, the anticipation of the opening of the solar farms will negatively affect nearby house prices. I argue that in anticipation of the opening of the solar farm, negative externalities already exist among local residents, as Kiel & McClain (1995) state that in the period predating the opening of an energy generating facility, a significant negative effect on surrounding house prices is present.

3 Methodology

The goal of this research is to measure the external effects caused by solar farms by identifying residential property transactions in the proximity of the solar farm before and after the construction and opening. These effects however, would be environmental and are not traded in the market. In order to measure this effect, one has to look at the actual buying behavior of people, as that reflects the actual valuation people assign to environmental effects. For residential properties, a common used method to measure these environmental non-market-traded effects, is the hedonic price model by Rosen (1974). He proposes a model in which the total price P, is determined by certain characteristics. In the context of houses, these characteristics can be broken down into property characteristics, such as size and construction year; and environmental characteristics, such as proximity to amenities and pollution. A simple statistical model of the hedonic pricing model for properties can look like this:

$$P = f(P_t, E_t)$$

In this model, price P is determined by property characteristics P_t and environmental characteristics E_t. In the hedonic pricing model the individual characteristics determine the value P of the property. If one of the individual characteristics changes, it is reflected in the price of the property. In other words, people will price in the existence of a solar farm according to this theory if it is part of one of the characteristics of a property. By measuring transactions in the proximity as well as further away it is possible to capture this effect.

Residential property transactions in the proximity of the researched solar farms are measured in different phases of the construction process. I start with the moment the solar farm gets a construction permit. When the permit is provided, the construction of the solar farm is likely and local residents presumably price in the future externalities in anticipation of the to-be constructed solar farm. The anticipation period between the permit date and the opening date will be referred to as Inter. I will also include residential property transactions two years before the moment the solar farm got a permit in order to measure the situation before the construction of the solar farm was confirmed. This period will be referred to as ante. I also include two years after the opening date of the solar farm and this period will be referred to as post.

In order to measure the effect of solar farms on residential property values, I use a difference-in-difference hedonic pricing model. By using this model, I can identify the influence the solar farm has on residential property values. I use a predefined target and control area to measure the difference between areas that are influenced by the solar farm and areas that are not influenced by the solar farm. I use the following empirical equation for this difference-in-difference hedonic pricing model:

$$Log(P_{it}) = \beta 0 + \beta 1 Target_i + \beta 2 Inter_t + \beta 3 Post_t + \beta 4 Target_i * Inter_t + \beta 5 Target_i * Post_t + \Sigma Z_{it} + \varepsilon_{it}$$

Where $Log(P_{it})$ is the value of residential property i, in the year of sale t. $Target_i$ is a dummy variable which takes the value of 1 if the transaction takes place in the target area and 0 if it is not the target area. $Inter_t$ is a dummy which takes the value of 1 if the transaction takes place after the date the solar farm got a permit and before the opening date of the solar farm and 0 if otherwise. $Inter_t$ measures the anticipation period leading up to the opening of the solar farm. $Post_t$ is another time related dummy. It takes the value of 1 if the transaction takes place after the opening date of the solar farm and 0 if the transaction happens before the opening date. $Target_i * Inter_t$ is an interaction variable which also works as a dummy variable. It is equal to 1 if the transaction is both in the target area and happens after the permit date and before the opening date. Otherwise it will be equal to 0. $Target_i * Post_t$ is another interaction variable and is also a dummy. $Target_i * Post_t$ takes the value of 1 if the transaction takes place in the target area and after the opening date of the solar farm, if both conditions are not met, it will be equal to 0. ΣZ_{it} is the sum of all control variables. It controls for both house and neighborhood characteristics. The controls I include are plot size, floor space, construction year and house type. I will also control for location and time-fixed effects by including categorical variables of the city and year of the transaction. Lastly, I also include the error term, ε_{it}.

I test for underlying assumptions of the regression. The results are presented in Table 10 in Appendix B. The Breusch-Pagan test indicates that heteroscedasticity exists. To solve this, I use robust standard errors in my regression. Furthermore, the Shapiro-Wilk W normality test indicates that the residuals are not normally distributed. As can be seen in Figure 3 in Appendix B, the residuals are not normal distributed. To solve this, I use robust standard errors in my regression. This does not completely solve the not normal distribution of the residuals, however, according to Pek et al. (2018), the assumption of normality can be relaxed with large enough sample size due to the central limit theorem. A sample size larger than 30 is considered as large enough for the central limit theory to apply, therefore my sample size is of sufficient size to relax the assumption of normality. In addition, the functional form test indicates that I have a functional form problem. However, I use a semi-logged functional form in line with prior research on this topic with a similar methodology, therefore I do not change my functional form. Furthermore, the tests indicate that no problems regarding multicollinearity, specification problems and Cook's distance are present.

Using a difference-in-difference hedonic pricing model with a target and control area is a broadly used strategy in similar research (e.g Davis, 2011; Gibbons, 2015; Hoen et al., 2015; Droes & Koster, 2016; Bauer et al., 2017; Tanaka & Zabel, 2018; Gaur & Lang, 2020; Jarvis, 2021; Droes & Koster, 2021). However, since the extent of the target area is unknown, the target and control areas need to be empirically determined. In order to determine these target and control areas, I compare various recent papers with a similar difference-in-difference approach on the effect of energy-related developments on residential property values in the proximity (see Table 1), as they can give useful insights into the extent of the target and control areas. Hoen et al. (2015), Gibbons (2015) and Droes & Koster (2016) use the difference-in-difference approach to research the effect of wind turbines on residential property values in the proximity. They use target groups between 1.61km (1 mile) and 4km and they use control areas between 3km and 14km. However, as wind turbines are visible and hearable from further away relative to solar farms, it is likely that the externalities also have an effect at a further distance. Therefore, it is likely that the target and control groups for research on solar farms should be smaller. Bauer et al. (2017) and Tanaka & Zabel (2018) researched the effect of nuclear plant closings on residential property values in the proximity. They use target areas of 4km and 5km and control areas of 25km and 40km. The externalities of nuclear power plants are likely to extend further than those of solar farms due to potential fallout hazards, which solar farms do not have. Therefore, it is likely that the target and control areas of solar farms should be smaller than when researching nuclear power plants. Davis (2011), did research on the effect of coal plants on surrounding house prices and he used a target area of 3.22km (2 miles) and a control area of 12.87km (8 miles). As coal plants are more visible and produce exhaust plumes and influence the air quality in the entire area it is in this case also likely that the target and control areas of solar farms should be smaller as solar farms do not produce these kinds of negative externalities.

Table 1. Target and control areas in papers using a difference-in-difference approach on the effect of energy related developments on residential property values in the proximity.

Paper	**Topic**	**Location**	**Target**	**Control**
Droes & Koster (2021)	Solar farms	Netherlands	1km	2-5km
Gaur & Lang (2020)	Solar farms	USA	1 mile	3 mile
Jarvis (2021)	Solar farms	USA	1-2km	5km
Droes & Koster (2016)	Wind turbines	Netherlands	2km	3km
Gibbons (2015)	Wind turbines	England	2-4km	14km
Hoen et al. (2015)	Wind turbines	USA	1 mile	3 miles
Davis (2011)	Power plants	USA	2 miles	8 miles
Tanaka & Zabel (2018)	Nuclear plants	USA	4km	40km
Bauer et al. (2017)	Nuclear plants	Germany	5km	25km

Gaur & Lang (2020), Droes & Koster (2021) and Jarvis (2021), all did a difference-in-difference analysis on the effect of solar farms on residential property values in the proximity. Gaur & Lang (2020) found a negative correlation within 1.61km (1 mile). Droes & Koster (2021) found a negative correlation within 1km and Jarvis (2021) did not find a significant effect with a target area of both 1km and 2km. Based on these former researches, I set the boundary of the target area at 1km. Gaur & Lang (2020), had a control area of 3.83km (3 miles); Droes & Koster (2021) used different control areas of 2km and 5km and Jarvis (2021) had a control area with a radius of 5km. In line with these papers, a control area between 2km and 5km is acceptable. However, with a control area of more than 3km, relatively many new villages and cities are included which are likely not comparable to the target area. Therefore, I argue based on prior research and the location of the solar farms that a control area between 1-2km and 1-3km is a good fit for this research. As a control group with a smaller radius is likely more comparable to the target group than a control group with a larger radius, I set the radius of the control group at 1-2km.

4 Data

The used data comes from multiple sources. For the data on residential property transactions in the Netherlands between January 2015 and October 2022, I use data provided by a database from the NVM, the Dutch real estate brokerage organization. The data is obtained through an internship at a NVM broker in 2022 and no NDA is signed. The extracted data is stored on my computer and will be deleted after completing this research. This database consists of approximately 69% of the total residential property transactions in the Netherlands (NVM, 2022). The database contains detailed information regarding property transactions. Besides sales price, address and the transaction date, additional property characteristics as plot size, floor space, construction year, building type, number of rooms are available as well. Only residential property transactions within the target area of 0-1km around the solar farm and the control area of 1-2km are included. The sample size consists of 3,741 residential property transactions. Residential property transactions from two years before the permit date of the solar farm up until two years after the opening date of the solar farm are included. This results in a sample of 3,741 residential property transactions between January 2015 and October 2022.

For the data on solar farms, I use a dataset from the Dutch government agency for entrepreneurship (RVO, 2021). This dataset consists of all known opened solar farms in the Netherlands on 1 January 2021. The dataset includes both solar farms located on land and water. In total, 272 solar farms are included with opening years ranging from 2012 to 2020. The dataset includes various additional characteristics of the solar farms, for instance, physical characteristics such as the location, the number of solar panels and the capacity in megawatts. Information on the date the solar farm received a permit and the opening is included as well. The dataset however, is not complete for all variables for all observations. As a result, I drop certain observations due to missing values. As one of my hypotheses is about the effect of the anticipation towards the opening, I include the permit date as a variable. I also include the opening date, as I need to measure the effect before and after the opening date. As a result, I drop 250 observations, as those are missing data on either the permit or opening date. If only the year instead of the specific date the solar farm got a permit or opened was included, I used the first of January of that year as date. In addition, if only the permit or opening month was available, I used the first of that month as date. In addition, it is important that residential property transactions are present in the proximity of the solar farm. Therefore, I exclude all solar farms without a village, city or another type of settlement in the defined target area of 1 kilometer. As a result, another 12 observations are dropped and 10 solar farm observations remain.

To construct one dataset to work with, I merge the two datasets. In order to do this, I use ArcGIS. In ArcGIS, I match the solar farms to the addresses of residential property transactions in the proximity. In addition, I calculate the distance in meters between the addresses and the closest point of the nearest solar farm. After this, I drop solar farms with less than 100 observations in either the target or control area in Stata[1]. This results in dropping five more solar farms and resulting in a total sample size of five solar farms. Figure 4 in Appendix C represents the locations of all solar farms in the used dataset of this research. In Table 2, the characteristics of the solar farms used in this research are represented.

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[1] The syntax do file is presented in Appendix E.

Table 2. The solar farms used in this research				
Solar Farm	**Location**	**MW**	**Permit date**	**Opening date**
Zonnepark Andijk	Andijk	15.2MW	2017	Nov 2018
Zonnepark Waterlanden	Goor	10.8MW	2017	Dec 2020
Stroomtuin IJlst	IJlst	2.6MW	2018	Jun 2020
Zonnepark Zierikzee	Zierikzee	14.1MW	2017	Dec 2018
Zonnepark Revelhorst	Zutphen	8.1MW	2019	Oct 2020

After merging the datasets, I winsorize the data at a 0.5% and 99.5% level. This results in a total of 3,741 residential property transaction observations. The summary statistics of these observations are presented in Table 3. The transaction price ranges between €98,500 and €845,000 with an average of €272,449. The distance to a solar farm ranges between 66.50 meter and 1999.95 meter with an average of 1157.04 meter. Furthermore, the majority of my datasets consists of residential properties constructed after 1970, which is not surprising given that most residential properties in the Netherlands have been built since then. Additionally, Zutphen has significantly more observations than other cities. As Zutphen is a large city and as the solar farm is located relatively close to residential properties, the sample size of Zutphen is relatively large compared to other cities. Most transactions take place in 2019 and 2020, as those years include residential property transactions in the proximity of all solar farms. The years 2015-2018 also include residential property transactions of all solar farms. However, 2019 and 2020 reported higher transaction numbers in general than the years 2015-2018.

Table 3. Summary Statistics of residential property transactions					
Property characteristics	**Observations**	**Mean**	**SD**	**Min**	**Max**
Price (EUR)	3.741	272.449	121.208	98.500	845.000
Living area (sq m2)	3.741	122.743	38.308	48	321
Plot size (sq m2)	3.741	290.210	462.465	0	4625
Distance (meters)	3.741	1157.04	480.25	66.50	1999.95
Apartment (1=yes)	348	0.093			
Construction Period					
<1900 (1=yes)	149	0.039			
1900-1945 (1=yes)	562	0.150			
1945-1960 (1=yes)	159	0.043			
1960-1970 (1=yes)	352	0.094			
1970-1980 (1=yes)	632	0.168			
1980-1990 (1=yes)	389	0.104			
1990-2000 (1=yes)	516	0.140			
2000-2010 (1=yes)	428	0.114			
2010-2022 (1=yes)	518	0.138			
City					
Andijk (1=yes)	367	0.098			
Goor (1=yes)	627	0.168			
IJlst (1=yes)	273	0.073			
Sneek (1=yes)	295	0.079			
Warnsveld (1=yes)	356	0.095			
Zierikzee (1=yes)	516	0.138			
Zutphen (1=yes)	1306	0.349			
Transaction Year					
2015 (1=yes)	117	0.031			
2016 (1=yes)	289	0.077			
2017 (1=yes)	473	0.126			
2018 (1=yes)	600	0.160			
2019 (1=yes)	716	0.191			
2020 (1=yes)	889	0.238			
2021 (1=yes)	382	0.102			
2022 (1=yes)	275	0.074			

Note: I use residential property transactions within 2 kilometers of solar farms.

Top and bottom are winsorized at 0.5% level.

The location of the five included solar farms is presented in Figure 4 in Appendix C. Furthermore, in Figures 5-9 in Appendix C, maps of the individual solar farms with surrounding residential property transactions are presented. In Table 4, the number of transactions per solar farm is presented. In addition, the specific transactions in target and control areas and in ante, inter and post are presented. As can be seen in Table 4, Zonnepark Revelhorst has relatively many residential property transactions. This is a consequence of being situated in a more urbanized area compared to the other solar farms in my sample. I will test for heterogeneity to see whether this affects my results later. In general, there are more transactions in my data set in the control area. A possible explanation could be that solar farms are mostly not located within urban areas. Ante, inter and post seems to be relatively evenly distributed among most solar farms. The exceptions are Zonnepark Waterlanden which had a relatively long inter-period between the permit and opening dates and Zonnepark Zierikzee, which has a large number of post observations relative to the observations in ante and inter. A possible explanation could be that the difference between the ante/inter periods and the post period in terms of buyer interest was relatively large in Zierikzee compared to other researched locations.

Table 4. Number of transactions per solar farm

Solar Farm	**Transactions**	**Target**	**Control**	**Ante**	**Inter**	**Post**
Zonnepark Andijk	367	155	212	112	115	140
Zonnepark Waterlanden	627	159	468	112	361	154
Stroomtuin IJlst	568	243	225	231	186	151
Zonnepark Zierikzee	516	183	333	81	106	329
Zonnepark Revelhorst	1.662	728	934	490	648	524

5 Results

The main results of the hedonic price difference-in-difference regression are presented in this section. In Table 5, the results are presented. As previously stated, I use a target area of 0-1000 meter and a control area of 1000-2000 meter to test my hypothesis. Column (1) consists of only the key variables without control variables, Column (2) includes property characteristics as control variables. Column (3) additionally includes location-fixed effects and Column (4) adds year-fixed effects to the regression. The key variables are Target, Post and Inter and the interactions are Target x Post and Target x Inter.

In Column (1), the results of a basic model with only the independent variable, the key dependent variables and their interactions included are presented. All key variables are positive and significant. The interactions are negative and significant. However, as no controls are included, the R^2

is very low with a value of only 0.099. Therefore, this model shows there is a correlation between the dependent and independent variables, however it does not explain the variability of the dependent variable lnPrice. To improve my model, I add property characteristic controls in the model in Column (2). As a consequence, the R^2 increases 0.677. The key variables Target, Post and Inter remain positive and significant and the interaction Target x Post remains negative and significant in this model. To further improve the model I add location characteristics in the model in Column (3). In model (3), the results are generally in line with the model of Column (2).

In Column (4), the baseline specification, I add year fixed effects to further improve the model. The results indicate that residential properties are 9.19%[2] more expensive post-opening of the solar farm. In the Inter period between the permit date and the opening date, residential properties are 5.65% more expensive relative to the period before the permit was provided. The higher prices during Post and Inter are presumably the result of the general trend of increasing residential property prices in the Netherlands between 2015 and 2022. Furthermore, the results indicate that residential properties in the target area are 3.45% more expensive than residential properties in the control area. The interaction Target x Post indicates that residential properties located in the target area after the opening of a solar farm decrease in value with on average 2.85%, in line with my first hypothesis. The interaction coefficient Target x Inter however, is not significant in the baseline results. The coefficient indicates a non-significant negative correlation between the property values in the target area and anticipation period between the permit date and the opening date of 2.22%. The negative coefficient is in line with my hypothesis, however not significant and therefore I reject my second hypothesis. As presented in Figure 1 and 2 in Appendix A, the parallel trend assumption is not violated.

The significant negative coefficient of Target x Post is in line with the limited previous research on this topic. Gaur & Lang (2020) found a negative effect of 1.7% within 1 mile (1.61km). Droes & Koster (2021), found a decrease of 2.6% within 1km and Maddison et al. (2022) found a 5.4% reduction within 750 meter. The negative effect of 2.94% in my baseline results is of similar magnitude as the findings in prior research. In addition, the insignificant negative effect in the anticipation period is in line with the results of Jarvis (2021), who also found no significant anticipation effect.

[2] (exp(0.088)-1)*100

Table 6. Regression results				
Variables	**(1)**	**(2)**	**(3)**	**(4)**
Target (1=yes)	0.077***	0.040***	0.032**	0.034**
	(0.023)	(0.014)	(0.014)	(0.014)
Inter (1=yes)	0.173***	0.154***	0.157***	0.055***
	(0.021)	(0.0122)	(0.011)	(0.018)
Post (1=yes)	0.336***	0.329***	0.330***	0.088***
	(0.021)	(0.013)	(0.017)	(0.017)
Target X Inter (1=yes)	-0.061**	-0.025	-0.025	-0.022
	(0.031)	(0.018)	(0.017)	(0.017)
Target X Post (1=yes)	-0.055*	-0.032*	-0.033*	-0.029*
	(0.031)	(0.019)	(0.018)	(0.017)
Property Characteristics	No	Yes	Yes	Yes
Location Fixed Effects	No	No	Yes	Yes
Year Fixed Effects	No	No	No	Yes
Observations	3.741	3.741	3.740	3.740
Adjusted R^2	0.099	0.677	0.717	0.736

Note: the dependent variable is the logarithm of sale price of the residential property transaction. I include five solar farms. Property characteristics include living area, plot size, construction year and house type. Location Fixed Effects include city and Year Fixed Effects include year of sale. Robust standard errors in parentheses. ***(p<0.01), **(p<0.05), *(p<0.10)

6 Sensitivity analysis

6.1 Alternative specification

In the baseline specification, the target area is 0-1 kilometer and the control area is 1-2 kilometer. Within the target area, distance from the solar farm might affect the degree to which the solar farm affects residential property prices (Gaur & Lang, 2020). Proximity to a solar farm may result in a greater impact. As this effect might not be linear, I divide the target area into rings of 250 meter in line with Van Duijn et al. (2016). I create dummy variables for each ring (0-250m, 250-500m, 500-750m, 750-1000m). With the dummies, which represent the distance rings within the target area within the difference-in-difference method, I generate an alternative specification of my baseline specification:

$$Log(P_{it}) = \beta 0 + \beta 1 R_z Target_i + \beta 2 Inter_t + \beta 3 Post_t + \beta 4 R_z Target_i * Inter_t + \beta 5 R_z Target_i * Post_t + \Sigma Z_{it} + \varepsilon_{it}$$

In this specification, R_z is the set of the four ring dummies. The four ring dummies take the value of 1 if a residential property is located within the specific ring. As the effects at each distance level might be different ante, inter and post the solar farm development, I include interactions between the ring dummies and $Post_t$ and $Inter_t$. Furthermore, I control for housing characteristics and location and year fixed effects, similar to my baseline specification.

Table 7 presents the regression results of the alternative specification. The key variables Post and Inter are similar to my baseline results. The interactions with Post and Inter are non-significant for the ring dummies 0-250, 250-500 and 500-750. This means that the residential properties are on average not affected by the establishment of a solar farm at these distances. This is a surprising outcome, as a strong effect close to the solar farm which decreases with increasing distance is more in line with the existing literature (Gaur & Lang, 2020). The results however, may be influenced by the relatively small number of observations in the dummies more proximate to the solar farms as presented in Table 11 in Appendix D. The interaction with the 750-1000 dummy, has the most observations and is the only significant and negative coefficient. This indicates that the effect is still present at a distance of 750-1000 meter. That a significant, negative effect is only present at this distance and not closer to the solar farm, goes against intuition and results of existing literature, thereby possibly indicating that the number of observations in the ring dummies closer to the ring dummies is too small.

Table 7. Regression results of alternative specification	
Variables	**(1)**
Inter (1=yes)	0.056***
	(0.017)
Post (1=yes)	0.086***
	(0.025)
Target (0-250) (1=yes)	0.058
	(0.042)
Target (250-500) (1=yes)	0.046*
	(0.025)
Target (500-750) (1=yes)	0.019
	(0.019)
Target (750-1000) (1=yes)	0.040**
	(0.018)
Target X Inter (0-250) (1=yes)	-0.020
	(0.055)
Target X Inter (250-500) (1=yes)	-0.012
	(0.033)
Target X Inter (500-750) (1=yes)	0.010
	(0.024)
Target X Inter (750-1000) (1=yes)	-0.063***
	(0.024)
Target X Post (0-250) (1=yes)	-0.001
	(0.059)
Target X Post (250-500) (1=yes)	-0.056
	(0.037)
Target X Post (500-750) (1=yes)	0.015
	(0.026)
Target X Post (750-1000) (1=yes)	-0.055**
	(0.023)
Property Characteristics	Yes
Location Fixed Effects	Yes
Year Fixed Effects	Yes
Observations	3.740
Adjusted R^2	0.734

Note: the dependent variable is the logarithm of sale price of the residential property transaction. I include five solar farms. Property characteristics include living area, plot size, construction year and house type. Location Fixed Effects include city and Year Fixed Effects include year of sale. Robust standard errors in parentheses. ***(p<0.01), **(p<0.05), *(p<0.10)

6.2 Heterogeneity

In this section, I test for heterogeneity between rural and urban regions and residential properties built before and after 2000. I test for heterogeneity among solar farms in urban and rural regions, as residential property prices in rural and urban regions are heterogenous (DiPasquale & Wheaton, 1996). This heterogeneity regarding solar farms is described by Gaur & Lang (2020). They found that the construction of a solar farm only affects properties in urban regions. To test for heterogeneity among rural and urban regions, I separate the solar farms and the surrounding areas based on whether they are located in rural or urban areas. If there are less than 500 inhabitants per square kilometer in the region of the solar farm, I register the solar farm as rural (CBS, 2020). One solar farm, Zonnepark Revelhorst, is located in an urban area and four solar farms are located in rural regions.

In Table 8, the results of the heterogeneity regressions are presented. In Column (1), the results of residential property transactions in rural regions are visible. Column (2) shows the results of residential property transactions in urban regions and Column (3) shows the baseline results. As presented in Table 8, the target area is more expensive in urban regions relative to the control area compared to my baseline results. Rural has a negative effect on target, however this coefficient is insignificant. Furthermore, rural increased more post opening than the baseline results. My results indicate that residential property prices in rural increased more in post compared to residential properties in urban regions, however my urban coefficient is not significant. This effect however, could be explained by the trends in the residential property market in the Netherlands. During the timespan of this research, deurbanization and faster increasing prices in rural areas last years were present in the Netherlands which explains this difference (Swagerman, 2021). Target x Post is negative and significant in urban regions. The coefficient is more negative in urban regions than in rural regions and my baseline results, however, the coefficient in rural regions and my baseline results are not significant. This indicates that the opening of solar farms only significantly negatively affect residential properties in urban regions. These indications are in line with Gaur & Lang (2020). They found that residential property values in rural areas are affected less by the development of solar farms relative to urban areas. They argue that this possibly could be caused by the fact that land is more abundant in rural areas and that the development of a solar farm does not impact land scarcity as much in rural areas.

Table 8. Heterogeneity, Rural			
Variables	**(1) Rural**	**(2) Urban**	**(3) Baseline results**
Target (1=yes)	-0.009	0.068***	0.034**
	(0.021)	(0.016)	(0.016)
Post (1=yes)	0.107***	0.123	0.088***
	(0.038)	(0.104)	(0.025)
Inter (1=yes)	0.082***	0.087	0.055***
	(0.031)	(0.103)	(0.017)
Target X Post (1=yes)	-0.008	-0.041*	-0.029
	(0.026)	(0.022)	(0.017)
Target X Inter (1=yes)	0.001	-0.024	-0.022
	(0.025)	(0.022)	(0.017)
Property Characteristics	Yes	Yes	Yes
Location Fixed Effects	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Observations	2.078	1.662	3.740
Adjusted R^2	0.729	0.765	0.733

Note: the dependent variable is the logarithm of sale price of the residential property transaction. I include five solar farms. Property characteristics include living area, plot size, construction year and house type. Location Fixed Effects include city and Year Fixed Effects include year of sale. Standard errors in parentheses. ***(p<0.01), **(p<0.05), *(p<0.10)

In addition, I test for heterogeneity based on construction year. I differentiate between residential properties constructed before and after 2000. Differences in the effects on older and newer houses might exist for various reasons. First, as newer houses have in general a better energy label in the Netherlands (CBS, 2016), it is possible that people who care more for the environment and purchase houses with a better energy label, also perceive solar farms more positively. Another driver of heterogeneity might be, that newer houses are in general constructed on the periphery of cities. As solar farms are also in general constructed outside cities, one could argue that the property value of newer houses are more affected by the construction of solar farms as they are in general closer to the solar farms.

In Table 9, the results of the construction year heterogeneity test are presented. In Column (1), the results of residential properties constructed before 2000 are presented. Column (2) shows the results of residential properties constructed after 2000 and Column (3) shows the baseline results. As presented in Table 9, Residential properties constructed after 2000 have a significant and higher coefficient in target compared to the baseline results. Furthermore, residential properties constructed after 2000 became significantly more expensive during the timespan of this research compared to the overall sample. Target x Post is only negative and significant for residential properties constructed after 2000. This indicates that the opening of solar farms only significantly negatively affect residential properties which are constructed after 2000. A possible explanation could be the aforementioned theory that newer houses are in general constructed on the periphery of cities, in greater proximity to solar farms. Therefore, the property values may be affected more by the construction and opening of solar farms.

Table 9. Heterogeneity, Construction Year

Variables	**(1) Before 2000**	**(2) After 2000**	**(3) Baseline results**
Target (1=yes)	-0.002 (0.016)	0.0756*** (0.022)	0.034** (0.014)
Inter (1=yes)	0.026 (0.021)	0.079** (0.034)	0.055*** (0.018)
Post (1=yes)	0.046 (0.030)	0.142*** (0.031)	0.088*** (0.017)
Target X Inter (1=yes)	-0.005 (0.020)	-0.014 (0.031)	-0.022 (0.017)
Target X Post (1=yes)	0.001 (0.021)	-0.069** (0.028)	-0.029* (0.017)
Property Characteristics	Yes	Yes	Yes
Location Fixed Effects	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Observations	2.795	945	3.740
Adjusted R^2	0.720	0.788	0.736

Note: the dependent variable is the logarithm of sale price of the residential property transaction. I include five solar farms. Property characteristics include living area, plot size, construction year and house type. Location Fixed Effects include city and Year Fixed Effects include year of sale. Robust standard errors in parentheses. ***(p<0.01), **(p<0.05), *(p<0.10)

7 Conclusion

This paper investigates the effect of solar farms on residential property values in the proximity. I argue that a solar farm affects residential property values in the proximity, as solar farms likely are perceived as a negative characteristic by local residents as a result of negative externalities associated with solar farms. I use a difference-in-difference hedonic pricing method with a sample of five solar farms and 3,741 property transactions which occur two year before the permit dates, between the permit dates and the opening dates and two year after the opening dates of the solar farms. The target area is 0-1 kilometer and the control area is 1-2 kilometer around the solar farms. My baseline results indicate a significant negative effect in residential property values in the target area in the post-opening period. These findings are in line with prior research (Gaur & Lang 2020; Droes & Koster 2021; Maddison et al. 2022), who found a significant negative effect to be present. I do not find a significant effect in the anticipation period.

Furthermore, this paper shows with an alternative specification that no significant effect exists in interactions between post and dummies of 0-250m, 250-500m and 500-750m. Residential properties located between 750 and 1000 meter however, are significantly negatively affected by the opening of a solar farm. The insignificance at closer distance is possibly caused by the small sample size, however the results do indicate that the effect is still present at a distance of 750-1000 meters. In addition, I show that that residential properties located in urban areas are affected significantly negative, while there is no significant effect in rural areas. Furthermore, I find that residential properties constructed after 2000 are significantly negatively affected by the construction of solar farms, whereas I find no significant results for residential properties constructed before 2000. I argue that newer houses are in general constructed at the periphery of cities, in greater proximity to solar farms. Therefore, the property values could be affected more by the construction and opening of the solar farms compared to older properties. However, further research is necessary to explain these outcomes. I could not test whether the decrease in property value reduces as a result of the energy crisis which started in 2022. This energy crisis increased interest in renewable and solar energy and therefore, the negative effect of solar farms on residential property prices might weaken as a result. This might be interesting for further research when the data is available.

A limitation of this research is the limited availability of information on permits in the solar farm sample. As a result, the sample size of included solar farm is smaller compared to similar research and as a consequence, the results of this research may be less generalizable compared to the existing literature on this subject.

Despite the fact that this research does not measure all effects caused by the opening of a solar farm for society as a whole, it does provide us with clear implications for effects on the residential property values. Therefore, solar farm developers, the government and other policymakers should take these effects into account when planning new solar farms. Policy should focus on decreasing the negative characteristics and externalities which cause the decrease in residential property values in the proximity. This is relevant for solar farm developers to keep the support of local residents and for policymakers in order to keep the region attractive for inhabitants. In addition, the Dutch government compensates homeowners if house prices decrease by more than 4% as a result of area developments. As my results indicate that house prices decrease by more than 4% caused by solar farm development in urban areas and/or with houses constructed after 2000, it is relevant for the government to implement policies to decrease the negative effects and externalities caused by solar farms. If the loss of residential property value is included in the development cost of a solar farm, the net present value might not be positive anymore. Therefore, a possible solution that would be most beneficial for society as a whole, might for instance be to not allocate solar farms in the proximity of residential areas in the future.

Appendix A: development of residential property prices in target and control area

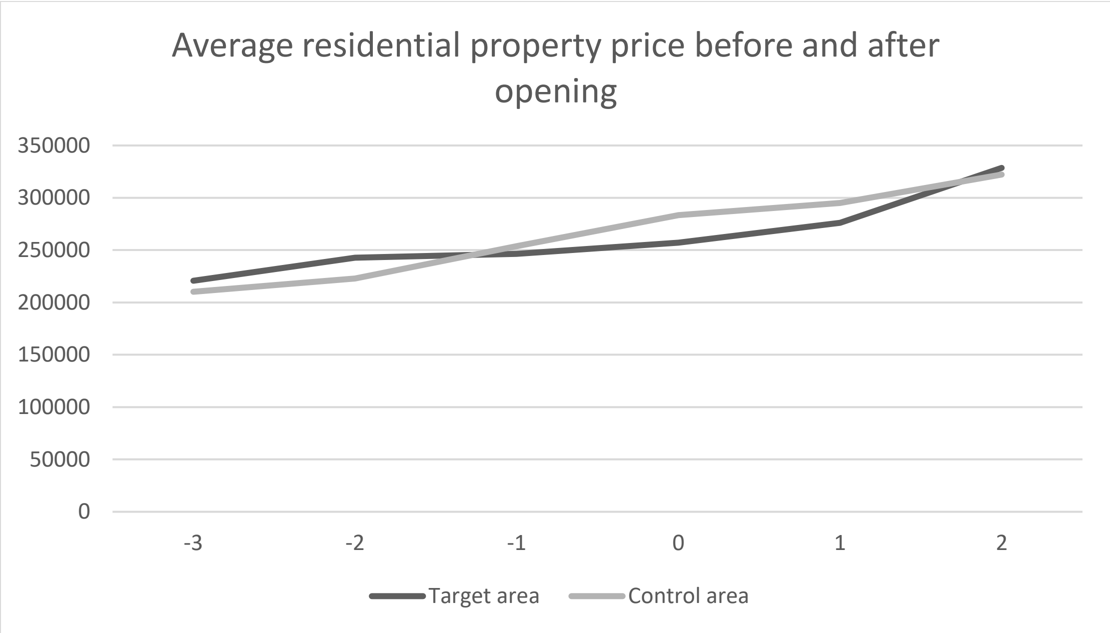

Figure 1: average residential property prices in target and control area in years before and after the opening of the solar farm. Calculated with average property prices from the sample. A relative negative price trend emerges for the target area approximately two years before the opening of the solar farm. The relative negative price trend of target appears to disappear approximately two years after the opening of the solar farm.

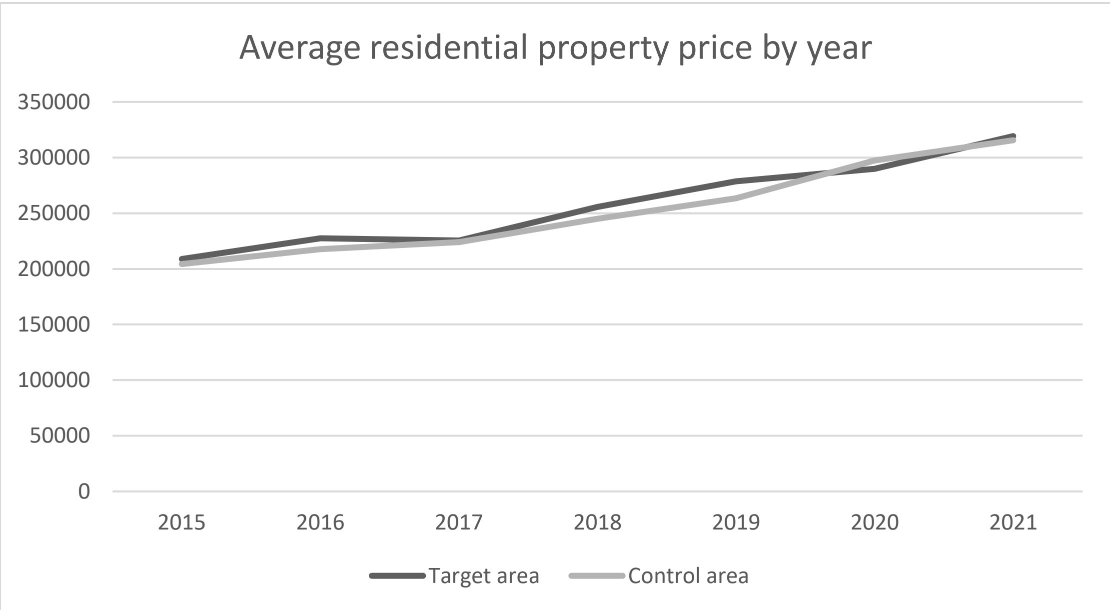

Figure 2: average residential property prices in target and control area per year. Calculated with average property prices from the sample. A similar trend between target and control area is visible. After 2019, average residential property prices in the target area become relatively cheaper. This can be explained by the opening dates of the solar farms which all opened between 2018 and 2020. The effect appears to disappear in 2021.

Appendix B: Regression checks

Table 10. Regression checks

Regression assumptions:	Test:	We seek values
1) heterokedasticity problem Chi2(1): 375.633 p-value: 0.000	Breusch-Pagan hettest	> 0.05
2) no multicollinearity problem 1.target : 3.97 19451960.buildingperiod : 6.36 19601970.buildingperiod : 3.24 19701980.buildingperiod : 12.65 19801990.buildingperiod : 3.16 19902000.buildingperiod : 1.42 20002010.buildingperiod : 1.40 20102022.buildingperiod : 5.04 2.housetype : 14.36 2.citynumerical : 5.31 3.citynumerical : 9.99 1.betweenopening : 15.70 4.citynumerical : 10.93 5.citynumerical : 13.46 6.citynumerical : 11.66 7.citynumerical : 13.64 2016.saleyear : 1.14 2017.saleyear : 2.92 2018.saleyear : 2.08 2019.saleyear : 2.14 2020.saleyear : 2.75 2021.saleyear : 2.35 2022.saleyear : 3.33 1.target#1.betweenopening : 5.40 1.postopening : 5.55 1.target#1.postopening : 7.22 livingarea_winsor : 12.16 plotsize_winsor : 15.34 15001900.buildingperiod : 11.49 19001944.buildingperiod : 8.90	Variance inflation factor	< 5.00
3) residuals are not normally distributed z: 9.969 p-value: 0.000	Shapiro-Wilk W normality test	> 0.01
4) no specification problem t: -16.417 p-value: 0.000	Linktest	> 0.05
5) functional form problem F(3,3706):166.625	Test for appropriate functional form	> 0.05

p-value: 0.000		
6) no influential observations	Cook's distance	< 1.00
no distance is above the cutoff		

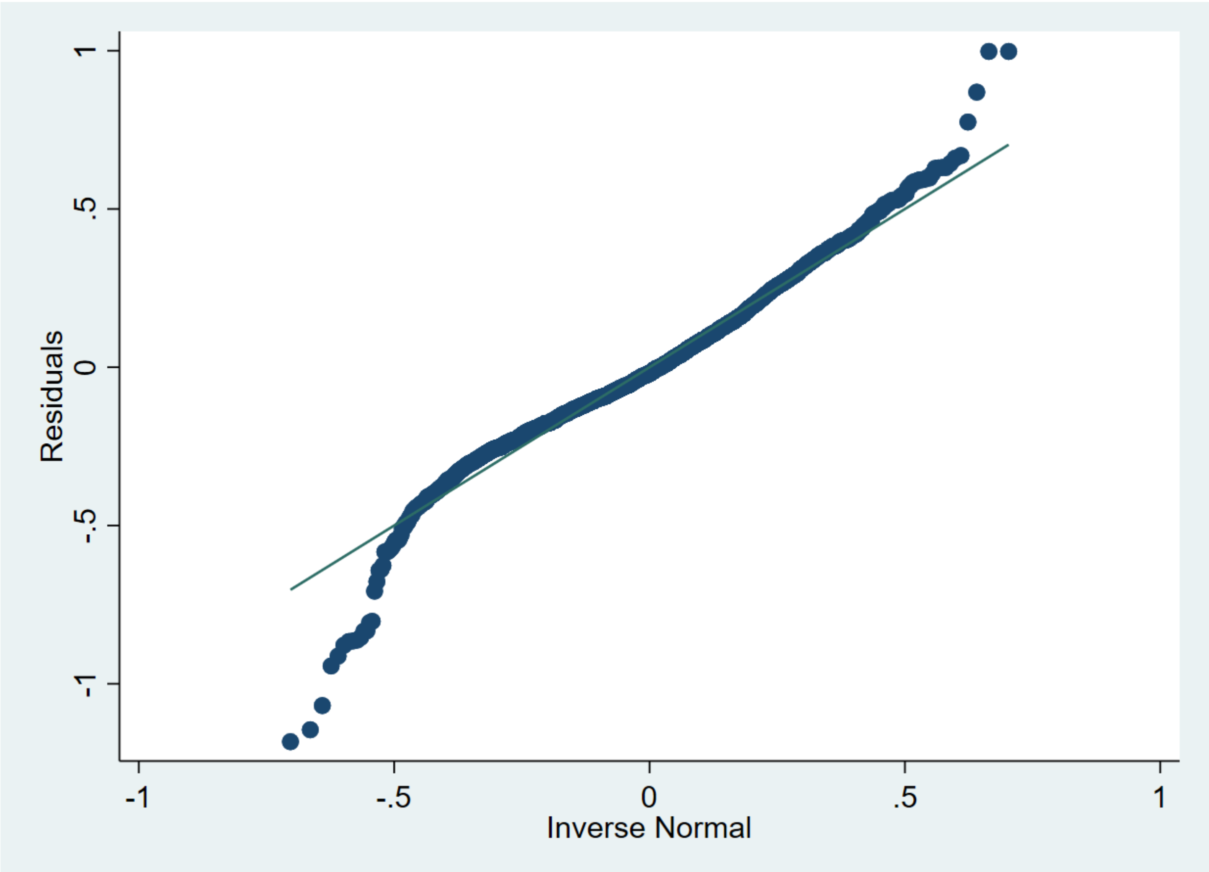

Figure 3: QQ-plot of residuals.

Appendix C: maps of solar farms and residential property transactions

Figure 4: Map of solar farms included in the sample.

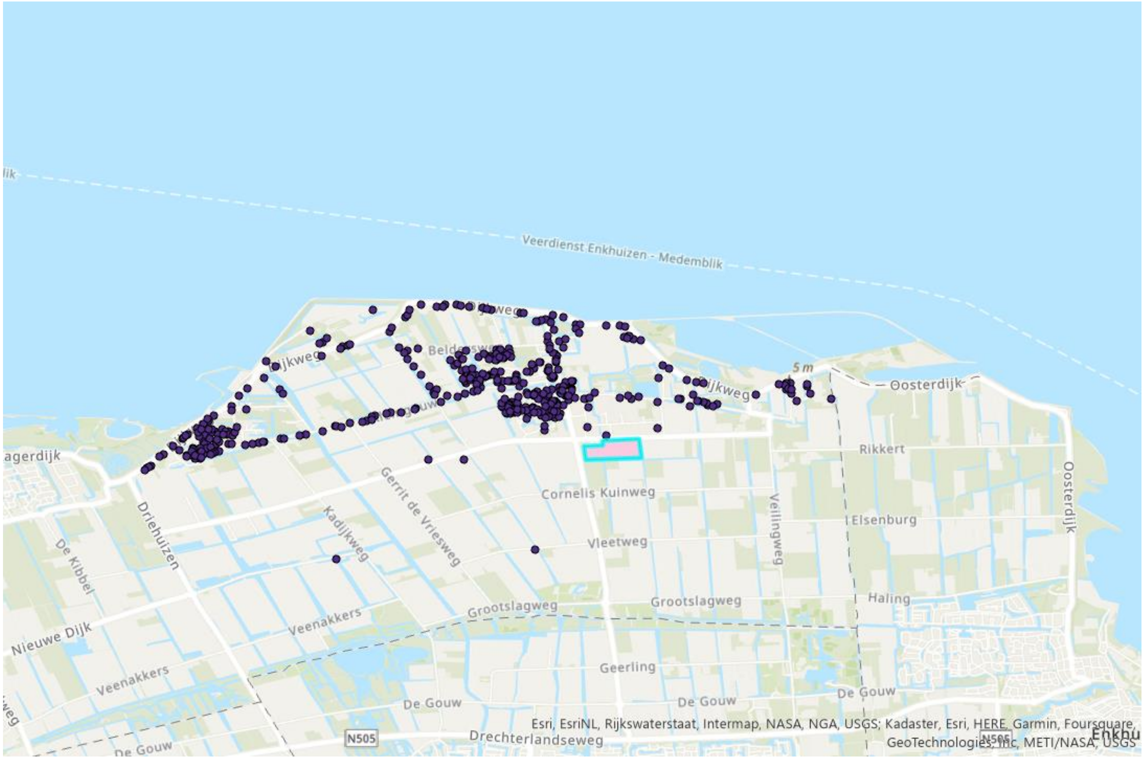

Figure 5: Zonnepark Andijk and residential property transactions between 2015 and 2020.

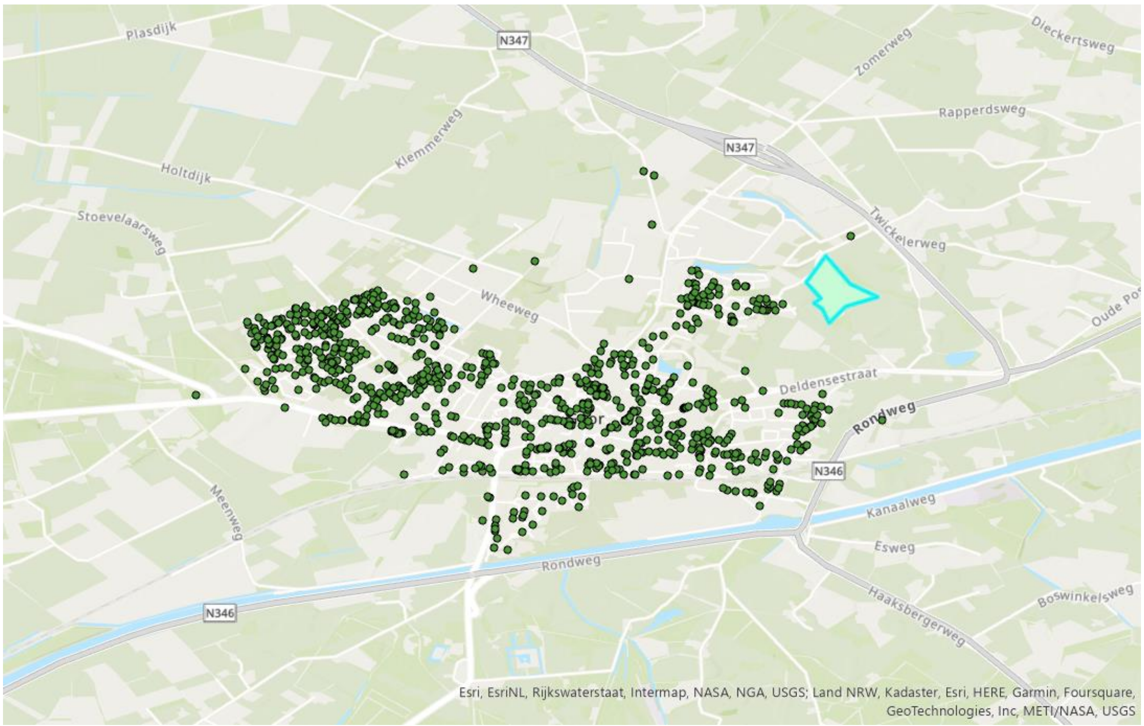

Figure 6: Zonnepark de Waterlanden and residential property transactions between 2015 and 2022.

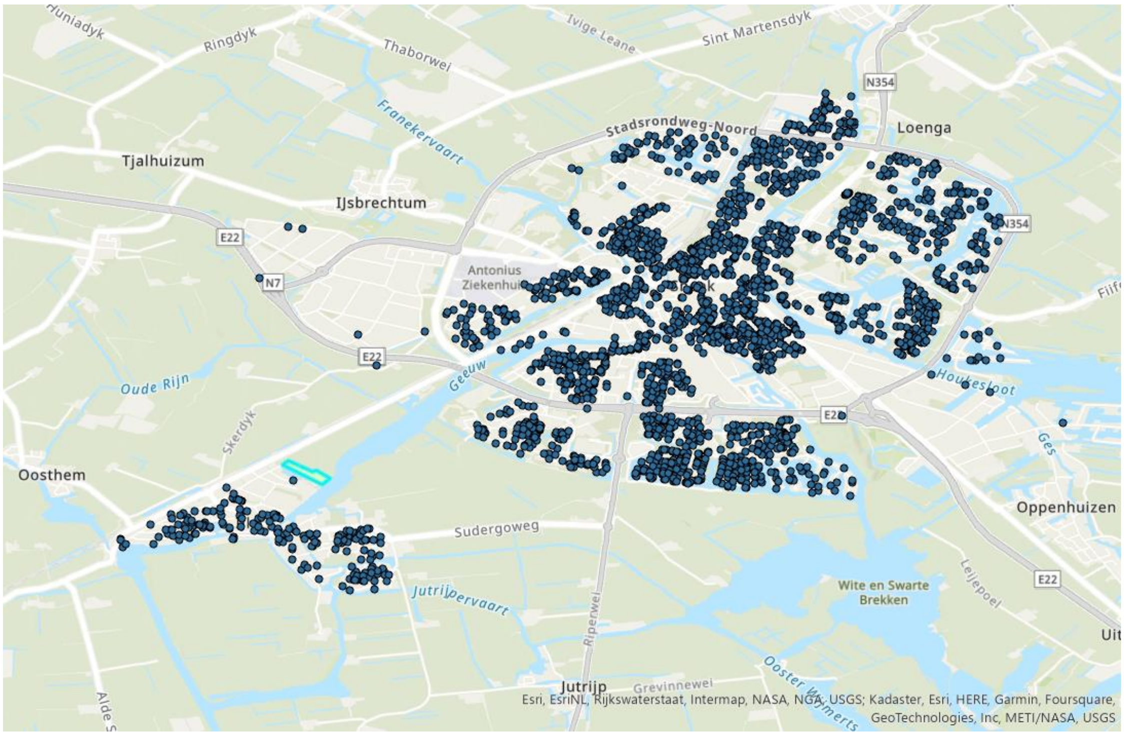

Figure 7: Stroomtuin IJlst and residential property transactions between 2016 and 2022.

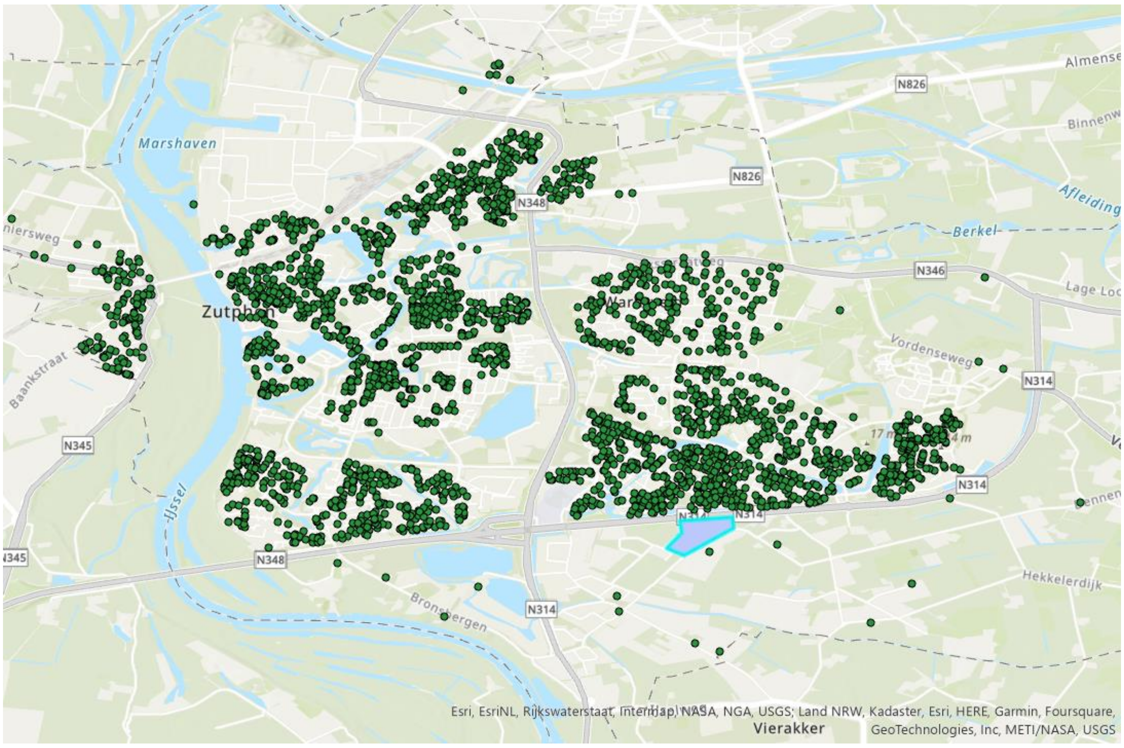

Figure 8: Zonnepark Revelhorst and residential property transactions between 2017 and 2022.

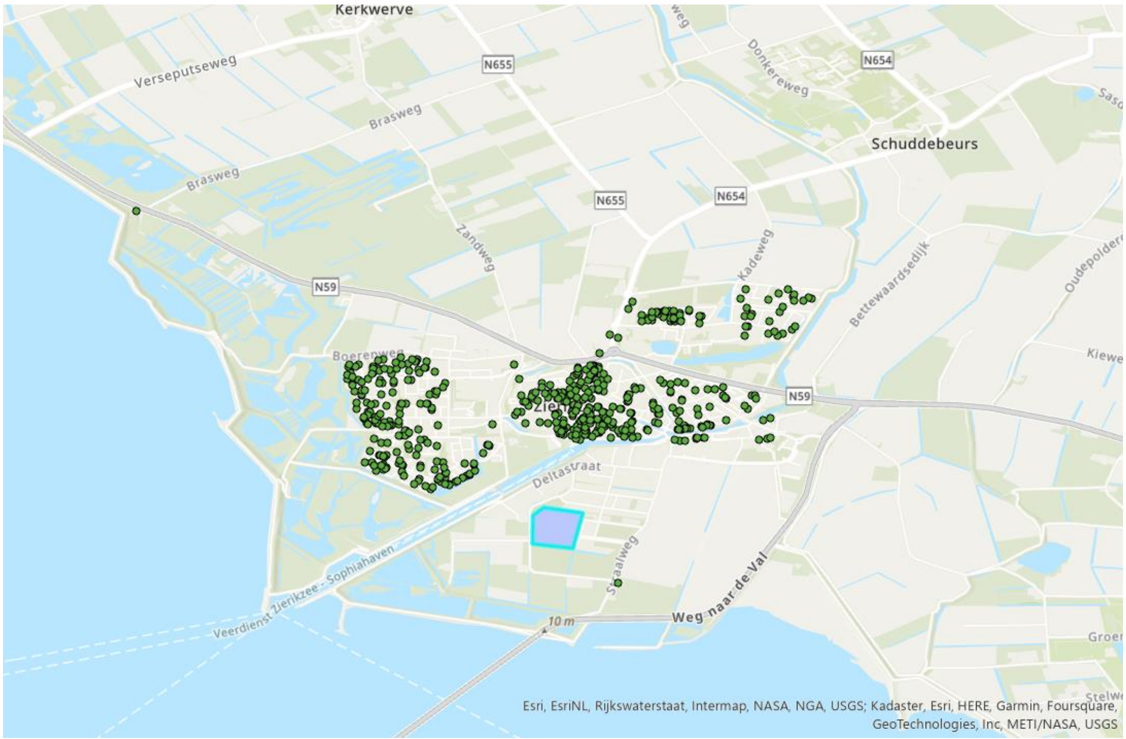

Figure 9: Zonnepark Zierikzee and residential property transactions between 2015 and 2020.

Appendix D: summary statistics of ring dummies in alternative specification

Table 11. Summary statistics ring dummies alternative specification

Property characteristics	Observations	Mean
Distance 0-250 (yes=1)	85	0.023
Distance 250-500 (yes=1)	248	0.066
Distance 500-750 (yes=1)	519	0.139
Distance 750-1000 (yes=1)	616	0.165

Appendix E: Stata do file

```
***GENERATING INTER AND POST DUMMIES PER SOLAR FARM***
clear

import excel "C:\Users\Jeroen\Documents\Universiteit\Real estate
studies\Thesis\Zonneparken\Data verkochte huizen\Zonnepark Zutphen\versie 2
zutphen\ZutphenWarnsveldGIS2.0.xlsx", sheet("Blad1_GeocodeAddresses_Proje_Ta") firstrow

drop if missing(Direction)
drop if NEAR_DIST >2000

//pre or post?
gen transactiondate=date(USER_Transactiedatum,"DMY")
format transactiondate %td

gen openingmonth = date("1 October, 2020","DMY")
format openingmonth %td
gen postopening = 0
replace postopening = 1 if transactiondate> openingmonth

gen licensemonth = date("1 January, 2019","DMY")
format licensemonth %td
gen betweenopening = 0
replace betweenopening = 1 if transactiondate > licensemonth & transactiondate < openingmonth

tab betweenopening
tab postopening

save

***COMBINING THE DATASETS OF DIFFERENT SOLAR FARMS***
clear

import excel "C:\Users\Jeroen\Documents\Universiteit\Real estate
studies\Thesis\Zonneparken\Data verkochte huizen\Gecombineerd\GecombineerdeDataset.xls",
sheet("Sheet1") firstrow clear

***DATA CLEANING, ORDERING AND GENERATION***
//price
destring USER_Huidige_prijs, gen(price)
generate lnprice = ln(price)

//target or control
gen target = 0
replace target = 1 if NEAR_DIST <1000
replace target = 0 if NEAR_DIST >1000
drop if NEAR_DIST >2000
```

```
//housing characteristic controls
//living area
	rename USER_Woonoppervlakte livingarea
//plot size
	rename USER_Perceel_oppervlak plotsize

//building period
drop if missing(real(USER_Bouwjaar___Periode))

destring USER_Bouwjaar___Periode, gen (buildingyear)

	gen buildingperiod = 0
replace buildingperiod = 15001900 if buildingyear > 1500 & buildingyear < 1900
replace buildingperiod = 19001945 if buildingyear >= 1900 & buildingyear < 1945
replace buildingperiod = 19451960 if buildingyear >= 1945 & buildingyear < 1960
replace buildingperiod = 19601970 if buildingyear >= 1960 & buildingyear < 1970
replace buildingperiod = 19701980 if buildingyear >= 1970 & buildingyear < 1980
replace buildingperiod = 19801990 if buildingyear >= 1980 & buildingyear < 1990
replace buildingperiod = 19902000 if buildingyear >= 1990 & buildingyear < 2000
replace buildingperiod = 20002010 if buildingyear >= 2000 & buildingyear < 2010
replace buildingperiod = 20102022 if buildingyear >= 2010

gen y15001900 = 0
replace y15001900 = 1 if buildingperiod == 15001900
gen y19001945 = 0
replace y19001945 = 1 if buildingperiod == 19001944
gen y19451960 = 0
replace y19451960 = 1 if buildingperiod == 19451960
gen y19601970 = 0
replace y19601970 = 1 if buildingperiod == 19601970
gen y19701980 = 0
replace y19701980 = 1 if buildingperiod == 19701980
gen y19801990 = 0
replace y19801990 = 1 if buildingperiod == 19801990
gen y19902000 = 0
replace y19902000 = 1 if buildingperiod == 19902000
gen y20002010 = 0
replace y20002010 = 1 if buildingperiod == 20002010
gen y20102022 = 0
replace y20102022 = 1 if buildingperiod == 20102022

//Housetype
encode USER_Soort_OG, gen (housetype)
//apartment=1 house=2)
gen apartment = 0
replace apartment = 1 if housetype == 1
```

```
//city (control)
encode City, gen (citynumerical)
gen andijk = 0
replace andijk = 1 if citynumerical == 1
gen goor = 0
replace goor = 1 if citynumerical == 2
gen ijlst = 0
replace ijlst = 1 if citynumerical == 3
gen sneek = 0
replace sneek = 1 if citynumerical == 4
gen warnsveld = 0
replace warnsveld = 1 if citynumerical == 5
gen zierikzee = 0
replace zierikzee = 1 if citynumerical == 6
gen zutphen = 0
replace zutphen = 1 if citynumerical == 7


//alternative specification distance
gen distance0250 = 0
replace distance0250 = 1 if NEAR_DIST<=250
gen distance250500 = 0
replace distance250500 = 1 if NEAR_DIST>250 & NEAR_DIST<=500
gen distance500750 = 0
replace distance500750 = 1 if NEAR_DIST>500 & NEAR_DIST<=750
gen distance7501000 = 0
replace distance7501000 = 1 if NEAR_DIST>750 & NEAR_DIST<=1000

//year (control)
gen saleyearnumber = transactiondate
gen saleyear = 0

replace saleyear = 2015 if saleyearnumber >= 20089 & saleyearnumber < 20454
replace saleyear = 2016 if saleyearnumber >= 20454 & saleyearnumber < 20820
replace saleyear = 2017 if saleyearnumber >= 20820 & saleyearnumber < 21185
replace saleyear = 2018 if saleyearnumber >= 21185 & saleyearnumber < 21550
replace saleyear = 2019 if saleyearnumber >= 21550 & saleyearnumber < 21915
replace saleyear = 2020 if saleyearnumber >= 21915 & saleyearnumber < 22281
replace saleyear = 2021 if saleyearnumber >= 22281 & saleyearnumber < 22646
replace saleyear = 2022 if saleyearnumber >= 22646

gen y2015 = 0
replace y2015 = 1 if saleyear == 2015
gen y2016 = 0
replace y2016 = 1 if saleyear == 2016
gen y2017 = 0
replace y2017 = 1 if saleyear == 2017
gen y2018 = 0
```

```
replace y2018 = 1 if saleyear == 2018
gen y2019 = 0
replace y2019 = 1 if saleyear == 2019
gen y2020 = 0
replace y2020 = 1 if saleyear == 2020
gen y2021 = 0
replace y2021 = 1 if saleyear == 2021
gen y2022 = 0
replace y2022 = 1 if saleyear == 2022


//heterogeneneity rural
//gen rural = 0
//replace rural = 1 if citynumerical == 1
//replace rural = 1 if citynumerical == 2
//replace rural = 1 if citynumerical == 3
//replace rural = 1 if citynumerical == 4
//replace rural = 1 if citynumerical == 6
//drop if rural==1

//heterogeneneity cities
//drop if citynumerical == 1
//drop if citynumerical == 2
//drop if citynumerical == 3
//drop if citynumerical == 4
//drop if citynumerical == 5
//drop if citynumerical == 6
//drop if citynumerical == 7

//heterogeneneity construction year
//drop if buildingyear < 2000
//drop if buildingyear >= 2000


//winsorizing
winsor livingarea, gen(livingarea_winsor) p(0.005)
winsor plotsize, gen(plotsize_winsor) p(0.005)
winsor lnprice, gen(lnprice_winsor) p(0.005)
winsor price, gen(price_winsor) p(0.005)


***REGRESSIONS***
//reg without controls
reg lnprice_winsor i.target##i.betweenopening i.target##i.postopening, vce(robust)

//reg without fixed effects
reg lnprice_winsor i.target##i.betweenopening i.target##i.postopening livingarea_winsor
plotsize_winsor i.buildingperiod i.housetype, vce(robust)
```

```
//reg without year fixed effects
reg lnprice_winsor i.target##i.betweenopening i.target##i.postopening livingarea_winsor
plotsize_winsor i.buildingperiod i.housetype i.citynumerical, vce(robust)

//reg baseline specification
reg lnprice_winsor i.target##i.betweenopening i.target##i.postopening livingarea_winsor
plotsize_winsor i.buildingperiod i.housetype i.citynumerical i.saleyear, vce(robust)

***log reg with alternative specification***
//reg lnprice_winsor i.distance0250##i.postopening i.distance0250##i.betweenopening
livingarea_winsor plotsize_winsor i.buildingperiod i.housetype i.citynumerical i.saleyear
//reg lnprice_winsor i.distance250500##i.postopening i.distance250500##i.betweenopening
livingarea_winsor plotsize_winsor i.buildingperiod i.housetype i.citynumerical i.saleyear
//reg lnprice_winsor i.distance500750##i.postopening i.distance500750##i.betweenopening
livingarea_winsor plotsize_winsor i.buildingperiod i.housetype i.citynumerical i.saleyear
//reg lnprice_winsor i.distance7501000##i.postopening i.distance7501000##i.betweenopening
livingarea_winsor plotsize_winsor i.buildingperiod i.housetype i.citynumerical i.saleyear

//reg lnprice_winsor i.distance0250##i.betweenopening i.distance250500##i.betweenopening
i.distance500750##i.betweenopening i.distance7501000##i.betweenopening
i.distance0250##i.postopening i.distance250500##i.postopening i.distance500750##i.postopening
i.distance7501000##i.postopening  livingarea_winsor plotsize_winsor i.buildingperiod i.housetype
i.citynumerical i.saleyear

***log reg with interactions with different years and inter post***
//reg lnprice_winsor i.saleyear##i.postopening i.saleyear##i.betweenopening livingarea_winsor
plotsize_winsor i.buildingperiod i.housetype i.citynumerical

***TABLES***
//quietly reg lnprice_winsor i.target##i.postopening i.target##i.betweenopening livingarea_winsor
plotsize_winsor i.buildingperiod i.housetype i.citynumerical i.saleyear
//vif

//tabstat lnprice_winsor i.target##i.postopening i.target##i.betweenopening livingarea_winsor
plotsize_winsor i.buildingperiod i.housetype i.citynumerical i.saleyear (count mean median min max
sd) labelwidth(32) varwidth(32) columns (statistics)

***ASSUMPTIONS CHECKS***
//regcheck

*heteroscadascity*
//estat hettest
//rvfplot, yline(0)

*normal distribution*
//predict resid_lnprice_winsor, residuals
//qnorm resid_lnprice_winsor
```

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