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Wind Turbines and House Prices Along the West of Ireland: A Hedonic Pricing Approach

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Wind Turbines and House Prices Along the West of Ireland: A Hedonic Pricing Approach

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Abstract

Wind energy will become the dominant source of electricity in Ireland, with the most ideal sites for wind electricity generation located along the west and southern coast. Despite the benefits associated with wind energy, wind turbines impose undesirable externalities on residents mainly through aural and visual pollution. In this paper, I perform a preliminary evaluation on the effect of wind turbines on listed house prices in Ireland. I employ a unique dataset of exact turbine locations with housing and amenity data in seven counties along the west and southern coast of Ireland. With this I conduct a hedonic pricing analysis incorporating spatial and temporal fixed effects. The analysis finds a robust and significant reduction in property value of -14.7% within 1km of a turbine. The effect increases with turbine height, count, and level of urban influence. However, there is evidence that the price effect decays over time, becoming insignificant after 10 years. Furthermore, exhibited effects likely persist beyond 1km, although they are not significant in this analysis. In short, the results presented in this paper are consistent with existing European studies, enforcing the recommendation that turbines should be constructed in highly remote areas to minimise impacts on residents.

Introduction

As global CO_2 emissions from fossil fuels and industry reach unprecedented levels (Forster et al., 2023), governments are under increasing pressure to limit emissions to prevent disruptive future climate scenarios (IPCC, 2023). One promising avenue towards reaching carbon neutrality is the decarbonisation of the electricity system, by advancing an unparalleled level of renewable electricity (European Commission, 2019). However, a growing body of evidence suggests that the widespread development of renewable electricity production presents new drawbacks in the form of undesirable externalities (Zerrahn, 2017).

Despite high rates of global acceptance for wind energy, there is an enduring attitude gap between wind power and wind turbine development (Wolsink, 2007). Wind turbines are often fiercely opposed at a local level (Devine-Wright, 2005), mainly due to imposed negative effects on wildlife (Barclay et al., 2007), noise emissions (Wang and Wang, 2015), deterioration of the surrounding visual aesthetics (Zerrahn, 2017), and flicker caused by the spinning blades (Phylip-Jones and Fischer, 2013).

It is necessary to quantify these effects two main reasons. Firstly, effects are highly localised; hence they are not appropriately distributed amongst the population who benefit from renewable electricity (Droes and Koster, 2021). Secondly, there is disagreement in the existing literature on the perceived level of undesirable externalities, with many studies finding insignificant effects. Evidence indicates that factors such as the degree of community engagement and compensation from developers can reduce the absolute magnitude of impacts (Heintzelman et al., 2017). This implies spatial heterogeneity at both an international and local level (Parsons and Heintzelman, 2022). Therefore, studies from other countries may not be applicable in an Irish context.

Literature review

Parsons and Heintzelman (2022) provide a detailed meta-analysis of the 18 key papers investigating wind power and property values. A study is considered “key” only if it matches most of a defined set of properties. These include use of hedonic pricing or repeated sales analysis, controlling for unobserved variables, and including a sufficient sample size of houses close to turbines.[1] Studies outside of this subset suffer from drawbacks such as insufficient sample size or lack of robustness checking.

As mentioned, there is mixed empirical consensus amongst the 18 key papers. While all European based studies consistently find significant negative impacts on residences near turbines, studies based in North America and Canada often report insignificant results. In studies with significant results, the authors demonstrate that impacts are non-linear over distance, using categorical distance bands or log transformations. In many cases, distance is employed as a proxy for all effects (Heintzelman and Tuttle, 2012; Hoen et al., 2015; Hoen and Atkinson-Palombo, 2016; Skenteris et al., 2019). Distance to turbine is highly correlated with both noise and visual disturbance. However, it introduces measurement error from unobserved variables, such as houses that are visually unaffected due to other obstructions.

Turbine impact measures can be improved with the inclusion of other accessible measurements associated with turbines. Dröes and Koster (2021) evaluate the effect of turbine height, finding significantly greater effects from turbines taller than 150m compared to turbines shorter than 50m, up to 2.5km away. Dröes and Koster (2016) evaluate the temporal behaviour of effects. They find that house prices remain significantly lower within 2km of turbines up to 8 years post-construction. Jensen et al. (2018) employ a weighted measure of turbine density. When accounting for the number of turbines up to 3km away from houses, they find that higher concentrations of turbines have significantly greater impacts on property values.

Recent analyses incorporate a view parameter to control for properties that are proximally close, but not visually affected by turbines (Parsons and Heintzelman, 2022). Some of these studies utilise a binary parameter calculated through a topographical viewshed analysis (Sunak and Madlener, 2015; Jarvis, 2021) and interact it with the distance variable to isolate effects. Other studies employ a non-binary measure, accounting for the degree of impact using categories ranging from "no-view" to "dominating" (Lang et al., 2014; Sunak and Madlener, 2015).

Of the 10 key studies in Europe, results consistently indicate significant negative reductions in house values within 2km of turbines. The magnitude of effect ranges from -25% (Sunak and Madlener, 2015) to -2% (Dröes and Koster, 2016). Price effects are greatest at close proximity to turbines and decrease non-linearly as distance increases. Most studies report insignificant

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[1] See Parsons and Heintzelman (2022) for the full list of criteria.

effects beyond 4km (Parsons and Heintzelman, 2022). Studies that include a view parameter find it has either insignificant effects (Dröes and Koster, 2016), or significant negative effects similar in magnitude to models that only employ distance controls (Sunak and Madlener, 2015). In the case of Dröes and Koster (2016), the insignificant result is attributed to a large measurement error. However, there is no obvious explanation as to why the effect is not increased with view control, considering houses that are visually unaffected are removed (Parsons and Heintzelman, 2022).

In contrast, almost all key studies conducted in North America find insignificant or mixed effects despite applying best practices (Hoen et al., 2011; Heintzelman and Tuttle, 2012; Vyn and McCollough, 2014; Lang et al., 2014; Hoen et al., 2015; Hoen and Atkinson-Palombo, 2016; Heintzelman et al., 2017; Vyn, 2018). There are several possible explanations for the difference in results between North America and Europe. Firstly, it is believed that residential sorting is more commonplace in North America than Europe due to increased mobility (Parsons and Heintzleman, 2022). Buyers with a preference for living close to turbines will replace the residents that are opposed to turbines (Tiebout, 1956). Other reasons include data quality, wind farm prevalence (Parsons and Heintzelman, 2022), and community compensation from developers (Heintzelman et al., 2017).

Overview

The aim of this paper is to investigate the impact of wind turbines on house prices in counties along the west coast of Ireland, including one neighbouring county on the southern coast (Cork). I apply a revealed preference method to the first comprehensive dataset of wind turbines in Ireland, combined with precise data of house prices and characteristics. While a difference-in-differences approach is a preferred method of potentially causal analysis in the literature (Jensen et al., 2018; Bishop et al., 2020; Dröes and Koster, 2021), I utilise a cross-sectional approach with spatial and temporal fixed effects due to sample size concerns. This method is used in similar studies to yield robust results (Jensen et al., 2018; Parsons and Heintzelman, 2022). Furthermore, I follow the recommended best practices detailed by Bishop et al. (2020) to provide plausible results.

In this paper I explicitly focus on the effect of proximity to wind turbines on listed property values in the case area. Without access to noise or viewshed information, distance to nearby turbines is a good proxy of all negative effects imposed by wind turbines (Dröes and Koster, 2016).

Secondly, I measure the magnitude of effect on house price over time. Considering the typical life of a wind farm can range from 20 to 25 years (IWEA, 2019), it is important to understand whether discount effects attenuate or persist over time.

Thirdly, I investigate the influence of turbine height in conjunction with proximity on property value. Dröes and Koster (2021) demonstrate that taller turbines have a larger magnitude of effect and impact at greater distances. Replicating this in an Irish context is of direct relevance for siting decisions.

Finally, this paper is the first to draw comparisons between future wind development zoning and existing wind turbines as a form of robustness checking.

The results of this analysis indicate a loss in house value of approximately 14.7% within 1km of a turbine, with greater impact from taller turbines, that are more recently connected, in rural areas of moderate to high urban influence. Furthermore, effects are dependent on the number of proximal turbines, with greater effects associated with a higher density of turbines. Finally, effects appear to dissipate over time, becoming insignificant after 10 years. These results are validated through several checks including a novel test for the impact on house price from living in proximity to an area zoned for wind development that features no turbines. This robustness test indicates that areas zoned for wind development do not feature a significant pre-existing price differential compared to the control areas.

The remainder of this paper is organised as follows; I first discuss the policy context surrounding wind energy development and the relevance of the hedonic pricing approach. I then describe the data and methods used in the analysis. I then present my findings and describe the robustness checks. Finally, I provide a discussion on the limitations of this analysis and outline avenues for future research.

Policy context

Despite the existence of similar analyses across Europe, there is a key difference that makes an Irish-based study necessary: wind energy is Ireland’s primary source of renewable electricity, contributing 80% of the renewable electricity produced (IWEA, 2020a). Moreover, it will continue to dominate the renewables sector in Ireland beyond 2030 (IWEA, 2020a, 2020b). The number of connected wind farms in Ireland has grown from 112 in 2010, to over 300 since 2020 (SEAI, 2023), with the number of turbines exceeding 2000 (see Figure 2). In comparison, wind energy contributes less than 50% of renewable electricity in most countries where previous analyses have been conducted (see Figure 1). Only Denmark maintains a high proportion of wind penetration but still substantially lower than Ireland.

Ireland intends to meet 80% of its electricity demand with renewable sources by 2030 (Government of Ireland, 2021). Wind energy will contribute the majority share of this electricity with more than a threefold increase in wind generated electricity, from 4GW in 2019, to 13.3GW in 2030. For comparison, by 2030 solar will account for only 2.5GW. This generation will come from a combination of onshore and offshore turbine development (IWEA, 2020a, 2020b).

The counties along the west and south coast of Ireland are of substantial importance for wind energy development. Not only do the seven observed counties contain over half of the current stock of wind turbines, approximately 1200, but these counties boast the greatest frequency of onshore sites in the country with an annual mean wind speed at 100m greater than 10m/s (SEAI, 2022). This indicates that these counties may be more lucrative and desirable for wind energy development going forward.

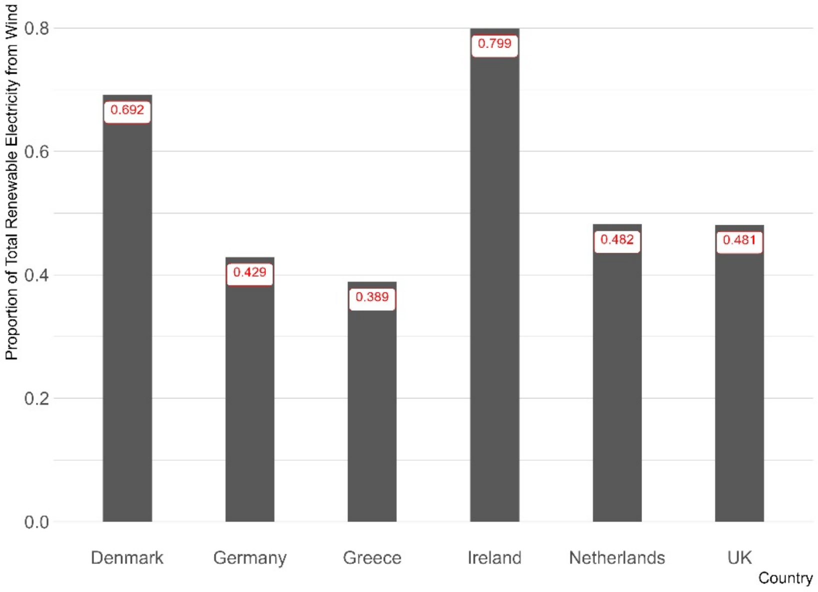

Figure 1: Mean proportion of wind produced electricity out of total renewable electricity in comparison countries, 2021-2023. Source: IEA (2023), own illustration.

Initially, the wind energy sector was supported through the Renewable Energy Feed-In Tariff (REFIT) scheme.[2] The REFIT scheme was subsequently replaced in 2020 by a competitive bidding process known as the Renewable Energy Support Scheme (RESS) (gov.ie, 2019). While feed-in tariffs have proven hugely successful in catalysing wind development (Dong, 2012), efficient producers collect a rent at the cost of the consumer. The competitive bidding process is designed to remove this additional rent. However, this can reduce the incentive for developers (Bhattacharya, 2019).

As development continues to increase, the most ideal sites for wind turbines are utilised first, leading developers to construct wind farms in possibly more controversial and contested locations (Parsons and Heintzelman, 2022). Not only are wind turbines becoming more commonplace in the Irish landscape, but modern turbines also boast increased hub heights and blade diameters. These turbines are visible from greater distances and loom larger when close by (Jensen et al., 2014; Jensen et al., 2018).

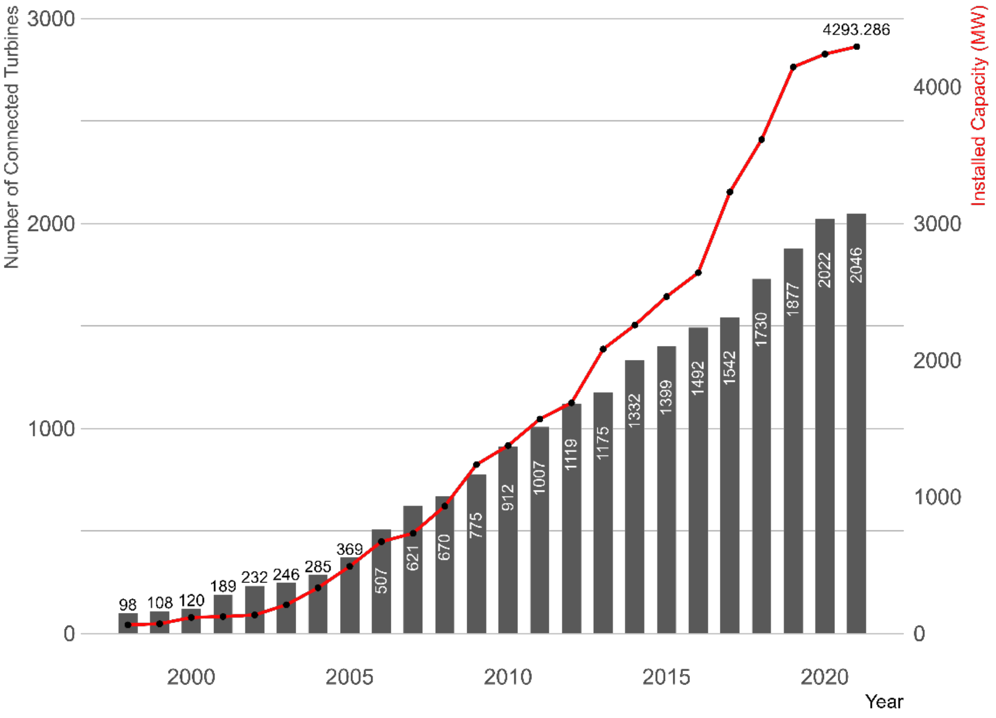

Figure 2: Cumulative number of connected turbines, and cumulative installed capacity, in Ireland 1998 - 2021. Source: SEAI Wind Atlas (2022), own data.

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[2] See Doherty and O'Malley (2011) for a full breakdown of the REFIT scheme in Ireland.

Theoretical background

Intuitively, local distaste towards the negative externalities of wind turbines is likely to be capitalised into the values of nearby houses. As such, a popular approach, to valuing the localised negative effects, is the hedonic pricing method.

The hedonic pricing method is a prevalent revealed preference approach for valuing environmental amenities, and disamenities, that do not have dedicated markets. It assumes that the overall value of a good is a function of the values of each characteristic of the good (Lancaster, 1966). In the context of the housing market, each individual house represents a unique combination of characteristics. The value of a house can be decomposed into the values of its individual attributes (Rosen, 1974). Therefore, the value of the disamenity can be isolated from the total value of the property. There are three key assumptions of hedonic pricing theory; markets are in equilibrium, people are knowledgeable of all available information and freely mobile, and buyers can purchase at continuous levels of each characteristic (Bishop et al., 2020).

The hedonic pricing method is frequently used to value environmental amenities or disamenities. This method has been implemented to identify the effects on house prices from air pollution (Harrison and Rubinfeld, 1978), noise pollution (von Graevenitz, 2018), flood risk (Bin et al., 2008; Gillespie et al., 2020), and sea views (Bin et al., 2008). Importantly, the hedonic pricing approach is becoming popular in analyses of renewable energy facilities including wind energy (Parsons and Heintzelman, 2022) and solar parks (Dröes and Koster, 2021).

Data and Methods

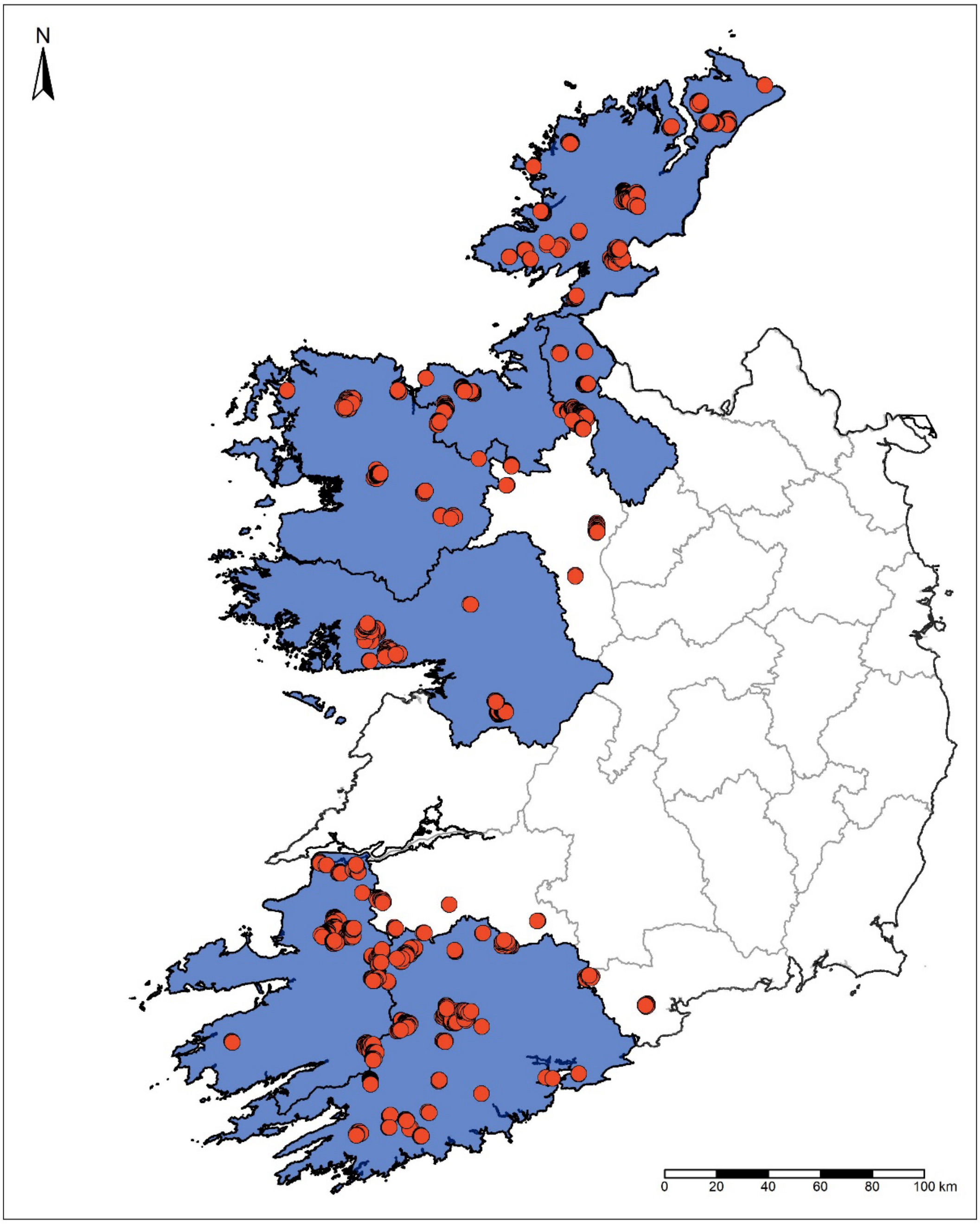

Figure 3: Location of wind turbines across the case area (shaded).

Case area and data

Investigating the consequences of wind turbine development on house prices, this study involves seven counties along the west coast of Ireland. From most Northerly to most Southerly the counties are: Donegal, Leitrim, Sligo, Mayo, Galway, Kerry, and Cork, see the shaded regions in Figure 3.

Individual turbines were identified using satellite imagery and assigned to the nearest known windfarm location (SEAI, 2023). Information on turbine hub height and rotor diameter was sourced from planning records (eplanning.ie, 2023). Figure 3 shows the locations of wind turbines. Some turbines from neighbouring counties are included, conditional on their proximity to observations within the case counties. There are three available dates relating to the development of turbines: submission of planning, approval of planning, and the connection date of the windfarm. In this analysis I use the connection date of the windfarm as the treatment date. However, there is empirical evidence that anticipation effects may arise before construction of any turbines (Parsons and Heintzelman, 2022). In total, there are 1,342 turbines in the study, with 366 turbines connected after 2016.

The housing data is a subset of a large national dataset of listings from daft.ie, a real estate website. This subset contains all listings, prices, and individual housing characteristics published between 2014 and 2020, inclusive, for the case counties. This time range represents a period of stability in the housing market. For the analysis, I use the last updated price, and associated date. As such, the updated time range is from 2016 to 2021, inclusive. Once corrected for outliers, there are 90,469 listings. I then calculate the distance from each house to the nearest turbine. I then further restrict the sample to houses within 15km of a turbine, in the post-connection period, a final count of 64,163 observations. An obvious limitation of listings is that the published price is not equivalent to the final sale price. However, it has been demonstrated that listing and transaction prices in Ireland are highly correlated during this period when used in hedonic analyses (Lyons, 2019; Gillespie et al., 2020).

Locational data on externally influential factors concerning man-made amenities, water-based amenities, and other natural amenities is publicly available from online government databases (data.gov.ie, 2023; EPA, 2023). I calculate the distance from these amenities to each property. Finally, each house is linked to its relevant Electoral District (ED), a small-scale spatial parcel that is employed as a spatial fixed effect. EDs are the smallest legally defined administrative areas in Ireland (CSO, 2017). The sample contains an average number of 74 houses per ED. Table 1 shows the summary statistics of the main factors concerning wind turbines, internal housing characteristics, and external influences on house values for both the treatment and control groups. A summary of all controls can be found in Appendix 1.

Table 1: Main descriptive statistics in treatment and control groups.

VARIABLES	≥5km of a wind turbine				<5km of a wind turbine			
Housing	mean	sd	min	max	mean	sd	min	max
ln (*Price (€)*)	12.07	0.616	10.31	14.51	12.04	0.608	10.31	14.38
Floor area (m^2)	149.0	502.2	0.100	48,562	152.3	210.7	0.100	8,093
Bedrooms	3.343	0.900	1	5	3.390	0.872	1	5
Bathrooms	2.134	1.008	1	8	2.149	1.023	1	7
Acres	0.0582	1.392	0	159	0.0584	1.144	0	93
Garden	0.557	0.497	0	1	0.563	0.496	0	1
Garage	0.174	0.379	0	1	0.199	0.400	0	1
Apartment	0.104	0.305	0	1	0.0372	0.189	0	1
Bungalow	0.0670	0.250	0	1	0.0956	0.294	0	1
Duplex	0.0107	0.103	0	1	0.00552	0.0741	0	1
House	0.818	0.386	0	1	0.860	0.347	0	1
Site	0.000855	0.0292	0	1	0.00126	0.0355	0	1
City	0.214	0.410	0	1	0.00103	0.0320	0	1
Satellite town	0.113	0.316	0	1	0.286	0.452	0	1
Independent urban town	0.224	0.417	0	1	0.111	0.314	0	1
Rural area with high urban influence	0.162	0.368	0	1	0.184	0.387	0	1
Rural area with moderate urban influence	0.123	0.329	0	1	0.148	0.355	0	1
Highly rural/remote area	0.164	0.370	0	1	0.270	0.444	0	1
Year of listing update	2019	1.706	2016	2021	2019	1.751	2016	2021
Environmental/spatial	mean	sd	min	max	mean	sd	min	max
ln (*300m contour line (m)*)	4.674	0.778	0	6.279	4.719	1.070	0	6.033
ln (*Nature reserve (m)*)	5.193	0.628	0	6.293	5.437	0.448	0.631	6.291
ln (*Coast (m)*)	4.195	1.596	0	6.527	3.827	1.790	0	6.379
ln (*Motorway Access (m)*)	7.240	0.202	6.508	7.772	7.295	0.134	6.660	7.712
ln (*Railway station (m)*)	4.570	1.458	0	7.282	5.047	1.013	0.422	7.278
ln (*Settlements (m)*)	0.887	1.475	0	5.182	1.200	1.654	0	4.896
ln (*Primary school (m)*)	2.022	0.896	0	4.504	2.049	0.951	0	4.595
ln (*Secondary school (m)*)	2.858	1.194	0	5.446	2.996	1.261	0	5.320
ln (*Bus stop (m)*)	1.535	1.173	0	4.579	1.863	1.261	0	4.979
Turbine related	mean	sd	min	max	mean	sd	min	max
Distance to nearest turbine (m)	9,798	2,887	5,000	15,000	3,490	1,014	123.7	4,999
Turbine height					114.5	32.66	48.50	152
ln (*Inverse distance to turbine (m)*)					0.417	0.377	0.000155	3.699
Weighted density					0.422	0.951	0.04	26.494
Nearest turbine <1,000m					0.0178	(0.132)		
Nearest turbine 1000m-1999m					0.0698	(0.255)	0	1
Nearest turbine 2000m-2999m					0.223	(0.416)	0	1
Nearest turbine 3000m-3999m					0.336	(0.472)	0	1
Nearest turbine 4000m-4999m					0.354	(0.478)	0	1
Number of observations	51,463				12,673			

Wind turbine measures

For the analysis, the final sample of houses is divided into two groups, houses within 0-5 km of the nearest turbine, the treatment group, and houses between 5-15 km of the nearest turbine, the control group. From Table 1, houses in both groups are mostly similar. However, properties in the treatment group are predominantly rural. Within the treatment group, houses are not evenly distributed with respect to proximity to the nearest turbine (see Figure 4). Only 225 houses lie within 1km of a turbine. Conversely, 8,743 houses lie between 3km and 5km of a turbine.

To approximate the relative impact of a turbine I calculate three separate metrics. The first is an inverted measure of distance to the nearest turbine that gives greater weighting to houses that are closer to turbines and assigns a weighting of zero to houses beyond 5km:

$$\ln(\text{Inverse distance to turbine(m)}) = \max\left(0, ln\left(\frac{5000}{distance_i}\right)\right)$$

The second measure separates houses into distance bands of 1km up to 5km away. The third measure uses a weighted density function to account for multiple turbines within a 5km radius of a house, with greater weight given to closer turbines. We define weighted density as:

$$\text{Weighted density}_i = \Sigma_{j=1}^{5} \frac{N_{i_{j*1000}}}{j^2}$$

Where N_{i_x} is the number of turbines within the $(x_{meters} - 1000_{meters}, x_{meters})$ radial distance band of house i. This metric assumes an inverse square effect from turbine density, i.e., doubling the distance implies the effect is quartered. This gives a far greater weight to turbines that are closer.

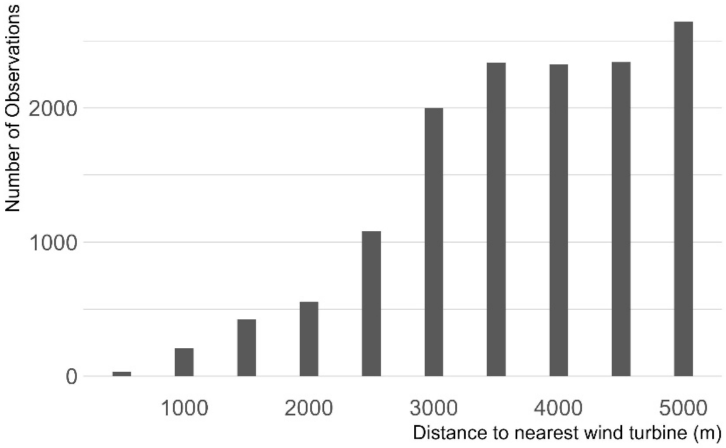

Figure 4: Observations within 500m bands up to 5km from a wind turbine.

I select 5km as the cutoff for the treatment group to maximise within-ED variation. Selecting a range too short would potentially compromise results as effects from turbines may extend outside of the treatment group into the control group. Choosing a range beyond 5km will limit variation within EDs as most houses in key EDs will be assigned to the treatment group.

Econometric framework

Adhering to the typical framework used in hedonic price analysis (Rosen, 1974; Bishop et al., 2020), I use the following conceptual model:

$$\text{Price}_i = \text{f}(I_i, Z_i, T_i, W_i) + e_i$$

Where the price of house i is a function of the internal characteristics I of the house (bedrooms, bathrooms, house type, etc.), the external characteristics Z of the house (distance to amenities etc.), including ED controls, the year and quarter of listing T, the influence from nearby wind turbines W (proximity, number of turbines, etc.), and some degree of random error e between the predicted price and the actual price.

For identification, I follow a similar strategy to Heintzelman and Tuttle (2012) and Jensen et al. (2018) using cross-sectional models with spatial and temporal fixed effects to account for omitted variable endogeneity influence. While a difference-in-differences approach is best practice, there are a limited number of observations within 5km of a turbine in the pre-construction period. Applying a difference-in-differences model might yield misleading results on such a small sample.

In keeping with best practices, I assume a nonlinear price function and employ a log-log or semi-log, depending on the variable, fixed effects model (Bishop et al., 2020). I use spatial fixed effects in the form of spatial dummy variables for ED and time fixed effects in the form of year and quarter of listing update. The baseline specification for this analysis is:

$$ln(Price_i) = \alpha + \beta I_i + \gamma Z_i + \sigma G_i + \delta T_i + \theta W_i + e_i$$

Where $Price_i$ is the updated listing price, I_i is a vector of dwelling characteristics, Z_i is a vector of location-specific amenities and controls, G_i is the ED fixed effect, T_i represents the time fixed effect (year and quarter), and W_i represents the variable of interest concerning wind turbines. In all models I report cluster-robust standard errors (Liang and Zeger, 1986). The full list of all controls is detailed in Appendix 2 column (6).

Beyond the baseline specification I test several additional hypotheses. Firstly, I investigate if the price effect changes over time. I separate the treatment and control samples based on the difference in years between listing and the connection date of the closest turbine. I evaluate the price effect of houses listed 0-5 years post connection, 5-10 years post connection, and 10+ years post connection.

Secondly, I test how turbine height impacts house price using turbines of overall height below 90m, from 90-125m, and above 125m. I approximate turbine height to be the hub height plus half of the rotor diameter.

Finally, I evaluate the effects of turbines on rural dwellings with different levels of urban influence, using defined urban and rural boundaries. There are six broad classifications for area type according to the CSO (2022). Houses fall into one of the following six classes: city, satellite town, independent town, rural area with high urban influence, rural area with moderate urban influence, highly rural/remote area. Due to a limitation of the housing sample, there are no observations under the "city" class within 3km of a turbine. Similarly, since turbines are typically constructed in rural areas (Parsons and Heintzelman, 2022) there are low observation counts for "satellite town" and "independent town". As such, there is only appropriate variation for houses in any of the three rural classes.

To identify effects, I interact the categories of interest (timing, height, and urban category) with distance to the nearest turbine. I then use linear combinations of parameters to isolate the effects of each interaction from the appropriate control group.

Results

Baseline effects

Table 2 contains the coefficients of the wind turbine distance and density measures described previously. The results of the model using distance bands, column (1), suggest a strong, significant, negative price effect of -14.7% on houses within 0-1km of a wind turbine when compared to houses between 5-15km of a turbine. However, there does not appear to be a significant effect outside of 1km from a turbine despite negative coefficients for houses between 1-2km and 2-3km.

The model in column (2) replaces the distance bands with the log of the inverted distance from the nearest turbine. This coefficient shows a significant negative effect of proximity to a turbine (see Figure 5).

In column (3), I replace the distance variable with the weighted density measure. This estimate suggests that each additional turbine within 1km of a house has a significant negative price effect of -2%. This result indicates that both turbine proximity and count are significantly impactful on house price.

These price effects are not necessarily robust since the siting of locations for wind turbine development is not random (Parsons and Heintzelman, 2012). Developers typically seek cheaper land when constructing a wind farm. While spatial fixed effects are employed to control for pre-existing price differentials, some level of uncontrolled endogeneity may pollute the treatment effect. Further on in this section I describe several robustness checks that validate these results.

Table 2: Baseline regression results: the impact of wind turbines on house prices

	Dependent variable: ln(*Listed house price*(€))			
	(1) Distance bands	(2) ln(*Inverse distance*)	(3) Weighted density	(4) Pre connection only
VARIABLES				
Nearest turbine 0-1km	-0.147***			0.119
	(0.044)			(0.120)
Nearest turbine 1-2km	-0.037			0.162*
	(0.036)			(0.084)
Nearest turbine 2-3km	-0.033			0.002
	(0.022)			(0.052)
Nearest turbine 3-4km	-0.001			-0.024
	(0.019)			(0.048)
Nearest turbine 4-5km	0.000			-0.018
	(0.016)			(0.031)
Nearest turbine 5-15km	*Base*			*Base*
ln(*Inverse distance*)		-0.057**		
		(0.025)		
Weighted density			-0.020***	
			(0.007)	
Constant	14.495***	14.451***	14.639***	3.220
	(2.301)	(2.298)	(2.369)	(8.709)
Housing characteristics	Y	Y	Y	Y
Locational characteristics	Y	Y	Y	Y
ED fixed effects	Y	Y	Y	Y
Year and quarter fixed effects	Y	Y	Y	Y
Observations	64,136	64,136	64,136	5,014
R-squared	0.571	0.571	0.571	0.611
Number of EDs	962	962	962	277

Robust and clustered standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

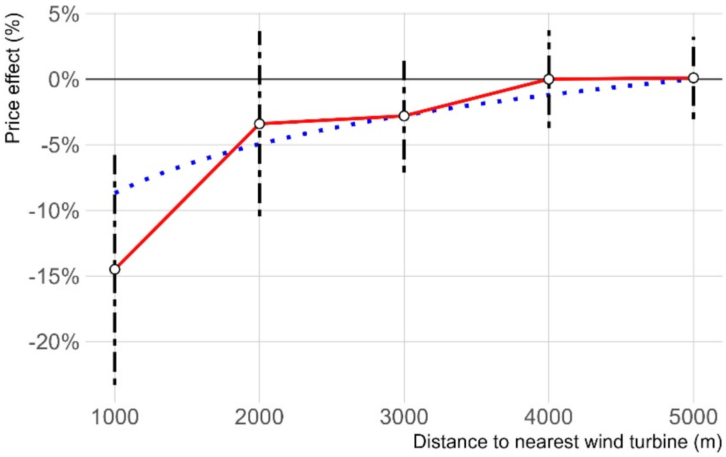

Figure 5: Baseline regression using distance bands with the 95% CI indicated by the vertical bars. The dotted line is the effect represented through log inverse distance.

Column (4) provides an initial degree of robustness checking. This regression uses only houses listed before the connection of the nearby windfarm. While there only a small number of observations in this sample (about 5,000 within 15km), the results do not show any significant negative pre-existing price differential. However, houses in the 1-2km band show a significantly greater value to the 5-15km band, 16.2%. Note there are only 96 observations in this group.

Figure 5 visualises the effect of proximity to turbines on house price. From the illustration there is a clear nonlinear relationship between distance to turbine and impact on price. Furthermore, we see that the log inverse distance measure captures a similar effect.

All baseline regressions use the same controls, these can be found in Appendix 2. The coefficients on the control variables are consistent with expectations. For example, bedrooms and bathrooms have positive impacts on price, and bungalows maintain significantly higher value than apartments. I perform a robustness test on the effect of the control variables on the variable of interest by excluding similar groups of controls. The effect of proximity to turbines remains consistent upon controlling for ED fixed effects and housing characteristics (see Appendix 2).

Time effects

Table 3 outlines the estimated effect of proximity to the nearest turbine given the property listing is updated within a given time post-connection of its nearest turbine. These results show a significant effect of -6.8% within 2-3km if the property listing is updated within 5 years of the connection of the turbine, and -20.4% if the property is within 1km. If the property listing is updated within 5-10 years of the turbine's connection date the only significant effect is in the 0-1km band, -14.7%. There is no significant effect if the property listing is updated beyond 10 years of the connection date. However, there remains a negative coefficient on the distance bands up to 3km. Note that the estimates within 1km are not significantly different from each other.

While these results indicate that effects on house price diminish over time there is a strong relationship between the age of a windfarm and turbine height. Older windfarms typically have shorter turbines that may be less pervasive on the landscape and may be better located (Dröes and Koster, 2021). Indeed, when I assess the effect of turbine height on house price, I find no significant effects from turbines shorter than 90m (see Table 4). Unfortunately, the sample is too small to control for both turbine height and timing of listing. The independent effect of each factor is unknown.

Table 3: The effect of duration of turbine connection on house price.

0-5 years	**0-1km**	**1-2km**	**2-3km**	**3-4km**	**4-5km**	**5-15km**
Estimate	-0.204	-0.058	-0.068	-0.018	-0.010	Base
SE	0.067	0.044	0.028	0.023	0.020	
	***		**			
5-10 years						
Estimate	-0.147	-0.031	0.002	-0.001	-0.013	Base
SE	0.057	0.055	0.030	0.026	0.019	
	***					
10+ years						
Estimate	-0.099	-0.023	-0.020	0.015	0.015	Base
SE	0.066	0.043	0.030	0.024	0.025	
*****=99%**	****=95%**	***=90%**				

Height effects

From Table 4, turbine height is influential on house price within 1km, with turbines taller than 125m incurring a greater discount (-22.9%) compared to medium sized turbines (-14.4%). Turbines shorter than 90m have no significant effect on house price but maintain a negative coefficient. While the negative effects of turbines above 125m persist up to 5km and effects for shorter turbines attenuate beyond 3-4km, these effects are not statistically significant. Furthermore, there is an unobserved relationship between turbine height and age that was discussed previously.

Table 4: The effect of turbine height on house price.

<90m	**0-1km**	**1-2km**	**2-3km**	**3-4km**	**4-5km**	**5-15km**
Estimate	-0.064	-0.020	-0.017	0.022	0.008	Base
SE	0.072	0.042	0.027	0.027	0.024	
90m-125m						
Estimate	-0.144	0.011	-0.055	-0.046	0.024	Base
SE	0.055	0.036	0.042	0.032	0.027	
	***					
>125m						
Estimate	-0.229	-0.084	-0.034	-0.010	-0.027	Base
SE	0.069	0.068	0.035	0.030	0.021	
	***					
*****=99%**	****=95%**	***=90%**				

Urban influence effects

Table 5 outlines the estimated effects from proximity to a wind turbine on house price for dwellings in three of the six area classes: rural areas with high urban influence, rural areas with moderate urban influence, and highly rural/remote areas. Cities, satellite towns, and independent urban towns are not reported due to sample size concerns. There are fewer than 10 observations within 1km of a turbine and no more than 60 observations within 1-2km across all three urban classes combined. Proximity to a wind turbine has a significant negative effect across all three rural classes with the greatest estimated effects in rural areas with moderate urban influence at −20.1%. Highly rural/remote areas show the smallest absolute effect within 1km at -11.5%. The magnitude of the induced discount appears to increase with in areas with urban influence compared to remote locations, although the difference is not significant.

Table 5: The impact of wind turbines on house price dependent on area classification.

	0-1km	1-2km	2-3km	3-4km	4-5km	5-15km
Rural areas with high urban influence						
Estimate	-0.167	-0.006	-0.028	0.006	0.014	Base
SE	0.061	0.035	0.031	0.030	0.022	
	***					
Rural areas with moderate urban influence						
Estimate	-0.201	-0.098	-0.039	-0.019	0.008	Base
SE	0.108	0.090	0.035	0.033	0.037	
	*					
Highly rural/remote areas						
Estimate	-0.115	-0.039	-0.025	-0.013	-0.031	Base
SE	0.058	0.038	0.037	0.032	0.026	
	**					
*****=99%**	****=95%**	***=90%**				

Robustness checks

As a test of robustness in the baseline results (see Appendix 2) I conduct a sensitivity analysis by varying the controls in the model. Starting from a naive model with only ED and year-quarter fixed effects alongside turbine proximity, I increase the complexity of the model through stepwise inclusion of similar groups of controls. The estimated effect of proximity to turbine remains consistent once basic housing characteristics are included. This suggests that the ED fixed effects and internal housing controls capture most unobserved housing and location characteristics.

Secondly, I perform a unique assessment of areas zoned for development. I show that areas marked for wind development, and nearby areas, do not display a significant pre-existing price differential. The location of wind turbine development is not random (Dröes and Koster, 2016) but in fact highly limited to areas outlined in local government policy (González et al., 2016). Areas acceptable for wind development are limited by wind speed, population density, proximity to existing transmission infrastructure, proximity to areas of natural beauty or historic significance, etc. (gov.ie, 2019). Areas suitable for wind energy development are typically of lower value compared to unsuitable areas. These pre-existing price differentials can be as great as -13% within 1.6km (Hoen et al., 2011).

Using maps from the Galway County Development Plan (2022), I compare areas in and around zones that are “acceptable in principle” for wind development to show that there is no significant pre-existing price differential within EDs for County Galway.

Table 6 shows three separate specifications of wind development in County Galway. Column (1) applies the baseline model to houses in only Galway. Once again, there is a strong significant negative effect for houses within 1km of a turbine (-34%). However, there is no significant effect of living near or within an area zoned for wind development, Column (2). The effect diminishes further when controlling for existing turbines in these areas, Column (3). Note, while the zoning effects are not significant, they are negative, although the magnitude of effect is small (about -3%).

The Galway County Development Plan outlined areas acceptable for development in 2022. Therefore, it is plausible that limited information on wind zoning was available when the houses were listed. Hence, any effects of proximity to the wind development zone are independent of individuals’ preference for wind turbines. The effects in Column (3) should measure the underlying price differential unrelated to existing wind turbines.

Table 6: The effect of living in or near an area suitable for wind development on house price.

	Dependent variable: ln(*Listed house price*(€))		
VARIABLES	(1) Galway turbines	(2) Galway zoning	(3) Galway Zoning X Nearest turbine >5km
Zone acceptable in principle (within zone)		-0.047	-0.035
		(0.088)	(0.100)
Zone acceptable in principle 0-1km		-0.120*	-0.112
		(0.071)	(0.070)
Zone acceptable in principle 1-2km		0.043	0.025
		(0.037)	(0.036)
Zone acceptable in principle 3-4km		-0.012	-0.012
		(0.033)	(0.033)
Zone acceptable in principle 4-5km		0.030	0.031
		(0.022)	(0.021)
Zone acceptable in principle >5km		*Base*	*Base*
Nearest turbine 0-1km	-0.340*		
	(0.181)		
Nearest turbine 1-2km	-0.078		
	(0.072)		
Nearest turbine 2-3km	-0.039		
	(0.043)		
Nearest turbine 3-4km	-0.032		
	(0.042)		
Nearest turbine 4-5km	-0.002		
	(0.036)		
Nearest turbine 5-15km	*Base*		
Constant	18.524***	21.564***	23.062***
	(4.777)	(4.697)	(4.673)
Housing characteristics	Y	Y	Y
Locational characteristics	Y	Y	Y
ED fixed effects	Y	Y	Y
Year and quarter fixed effects	Y	Y	Y
Observations	14,534	14,173	14,173
R-squared	0.581	0.582	0.584
Number of ed_id_encrypted	191	191	191

Robust standard errors in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Discussion

In this paper I investigate the effects of proximity to wind turbines on house prices in counties along the west coast of Ireland using a cross-sectional approach with spatial and temporal fixed effects. I find a significant and robust discount of 14.7% on properties within 1km of a wind turbine. Additionally, I identify significant effects from turbine density, a reduction in value of -2% per turbine within 1km. While effects appear to persist up to 3km, they are not statistically significant. Back-of-the-envelope calculations suggest that the total loss in value for houses within 1km of a turbine in the case counties is approximately €6.8 million.

I present evidence that taller turbines incur a greater discount than shorter turbines. Additionally, I display evidence of heterogeneity in effect dependent on the level of urban influence in the surrounding population. To validate my results, I perform a novel test of robustness using zoning data to demonstrate that there is an insignificant price differential in and around areas zoned for wind development compared to areas that are not zoned. Despite the negative effects induced by wind turbines, my analysis shows that effects attenuate over time, becoming insignificant beyond 10 years post-connection.

Limitations and future research recommendations

There are several obvious limitations of this study, many of which are related to sample size issues. The next course of action should be to evaluate the effects using a country-wide sample.

Firstly, I find no significant reduction in house price beyond 1km for all specifications except for turbines connected 0-5 years before the property listing. Within 1km of a turbine there are only 225 observations in the baseline model. This decreases further with the interaction models. Empirical evidence suggests that significant effects on house price can persist as far as 4km away from turbines (Parsons and Heintzelman, 2022). However, cluster-robust standard errors render effects at extended distances insignificant, despite negative coefficients. In addition, due to the spatial fixed effects, I rely on within-ED variations, limiting inferential power.

Secondly, there is an unobserved relationship between turbine height and the time of connection. Older turbines are typically shorter and better sited, while newer turbines are taller and more likely to be placed in more contested locations (Parsons and Heintzelman, 2022). Shorter turbines are less intrusive on the surrounding landscape. Therefore, there is an unobserved relationship between these two factors that is unaccounted for in the analysis. With a larger sample size, interaction effects can be employed to separate these effects.

Thirdly, empirical evidence suggests that turbines have a greater impact on urban areas compared to rural areas (Dröes and Koster, 2016). In this study I show that urban influence in a rural area may increase the absolute effect of the turbines on property values. However, I lack observations in urban areas to perform a direct rural-urban comparison.

Fourthly, my analysis of wind development zones is limited to Galway due to data availability issues. This analysis should be extended across all counties in the study to improve its validity. Furthermore, the absence of a significant pre-existing price differential in current zoned areas is not definitive proof that a pre-existing differential was not present in locations where turbines are currently connected. Hence, there is a requirement for more observations in the pre-connection period to test for this.

Similarly, having more observations in the pre-connection period would enable a difference-in-differences approach, a more definitive form of causal analysis. It would also allow testing for anticipation effects from turbines before construction. Conducting a difference-in-differences study would remove a large portion of the endogeneity from unobserved variables. Such an analysis should also vary the treatment period to test for impacts from planning approval.

While proximity is an appropriate proxy for all turbine externalities, it is still susceptible to confounding from unobserved variables. Houses may be proximally close to turbines but visually unaffected due to obstruction from other houses or features of the natural terrain. These properties may bias the absolute effect downwards if uncontrolled for. A recommended solution is the use of viewshed analysis to improve the accuracy of effect estimates.

Conclusion

It is clear from the analysis that turbines can incur a discount on nearby properties. However, there is evidence to suggest that the price effect is not persistent and can be minimised through siting decisions.

As renewable policies progress, the west and south of Ireland will likely continue to see disproportionately greater numbers of wind energy developments compared to the rest of the country. Therefore, the results outlined in this paper have important implications for policy, especially in terms of siting locations for wind turbine development. While it is important to reach climate targets through growth in renewable electricity production, it is necessary do so at a minimal cost to the public by focusing developments to remote areas with limited urban influence.

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Appendix

VARIABLES	≥5km of a wind turbine				<5km of a wind turbine			
Housing	mean	sd	min	max	mean	sd	min	max
Price (€)	209,431	137,629	30,000	2.000e+06	201,376	126,628	30,000	1.750e+06
ln (*Price (€)*)	12.07	0.616	10.31	14.51	12.04	0.608	10.31	14.38
Floor area (m^2)	149.0	502.2	0.100	48,562	152.3	210.7	0.100	8,093
Bedrooms	3.343	0.900	1	5	3.390	0.872	1	5
Bathrooms	2.134	1.008	1	8	2.149	1.023	1	7
Acres	0.0582	1.392	0	159	0.0584	1.144	0	93
Garden	0.557	0.497	0	1	0.563	0.496	0	1
Garage	0.174	0.379	0	1	0.199	0.400	0	1
Detatched	0.419	0.493	0	1	0.494	0.500	0	1
End of terrace	0.036	0.187	0	1	0.037	0.188	0	1
Semi-detatched	0.253	0.435	0	1	0.232	0.422	0	1
Terraced	0.089	0.285	0	1	0.232	0.281	0	1
Townhouse	0.019	0.138	0	1	0.011	0.104	0	1
Apartment	0.104	0.305	0	1	0.0372	0.189	0	1
Bungalow	0.0670	0.250	0	1	0.0956	0.294	0	1
Duplex	0.0107	0.103	0	1	0.00552	0.0741	0	1
House	0.818	0.386	0	1	0.860	0.347	0	1
Site	0.000855	0.0292	0	1	0.00126	0.0355	0	1
City	0.214	0.410	0	1	0.00103	0.0320	0	1
Satellite town	0.113	0.316	0	1	0.286	0.452	0	1
Independent urban town	0.224	0.417	0	1	0.111	0.314	0	1
Rural area with high urban influence	0.162	0.368	0	1	0.184	0.387	0	1
Rural area with moderate urban influence	0.123	0.329	0	1	0.148	0.355	0	1
Highly rural/remote area	0.164	0.370	0	1	0.270	0.444	0	1
Year of listing update	2019	1.706	2016	2021	2019	1.751	2016	2021
South	0.0773	0.267	0	1	0.0797	0.271	0	1
West	0.0457	0.209	0	1	0.0424	0.201	0	1
Southwest	0.0144	0.119	0	1	0.0100	0.0997	0	1
Period	0.0121	0.109	0	1	0.0163	0.127	0	1
Edwardian	0.000127	0.0113	0	1	0.000573	0.0239	0	1
Balcony	0.0565	0.231	0	1	0.0348	0.183	0	1
Victorian	0.00236	0.0485	0	1	0.00573	0.0755	0	1
Georgian	0.00368	0.0605	0	1	0.00351	0.0592	0	1
Baywindow	0.117	0.321	0	1	0.126	0.332	0	1
Corner house	0.00310	0.0556	0	1	0.00423	0.0649	0	1
Utility	0.407	0.491	0	1	0.425	0.494	0	1
Conservatory	0.0578	0.233	0	1	0.0640	0.245	0	1
Granny flat	0.00636	0.0795	0	1	0.00681	0.0822	0	1
Culdesac	0.0889	0.285	0	1	0.0925	0.290	0	1
Jacuzzi	0.0335	0.180	0	1	0.0358	0.186	0	1
Wardrobe$_f$	0.308	0.462	0	1	0.234	0.423	0	1
Wardrobe$_w$	0.0678	0.251	0	1	0.0749	0.263	0	1
Wetroom	0.0247	0.155	0	1	0.0310	0.173	0	1
Underfloor	0.0216	0.145	0	1	0.0196	0.139	0	1
Ensuite	0.383	0.486	0	1	0.371	0.483	0	1
Fireplace	0.436	0.496	0	1	0.455	0.498	0	1
Stove	0.137	0.344	0	1	0.154	0.361	0	1
Aga	0.0651	0.247	0	1	0.0798	0.271	0	1
Burner	0.00221	0.0470	0	1	0.00294	0.0541	0	1
Solarpanel	0.0166	0.128	0	1	0.0423	0.201	0	1
French doors	0.0690	0.254	0	1	0.0721	0.259	0	1
High ceiling	0.0137	0.116	0	1	0.0156	0.124	0	1
Corniced	0.0238	0.152	0	1	0.0349	0.184	0	1
Refurbished	0.0640	0.245	0	1	0.0705	0.256	0	1
Double Glaze	0.203	0.402	0	1	0.246	0.431	0	1
PVC	0.184	0.388	0	1	0.227	0.419	0	1
PVCu	0.00913	0.0951	0	1	0.0110	0.104	0	1
Brands	0.0146	0.120	0	1	0.0164	0.127	0	1
Environmental/spatial	mean	sd	min	max	mean	sd	min	max
ln (*300m contour line (m)*)	4.674	0.778	0	6.279	4.719	1.070	0	6.033
ln (*Nature reserve (m)*)	5.193	0.628	0	6.293	5.437	0.448	0.631	6.291
ln (*Coast (m)*)	4.195	1.596	0	6.527	3.827	1.790	0	6.379
ln (*Motorway Access (m)*)	7.240	0.202	6.508	7.772	7.295	0.134	6.660	7.712
ln (*Railway station (m)*)	4.570	1.458	0	7.282	5.047	1.013	0.422	7.278
ln (*Settlements (m)*)	0.887	1.475	0	5.182	1.200	1.654	0	4.896
ln (*Primary school (m)*)	2.022	0.896	0	4.504	2.049	0.951	0	4.595
ln (*Secondary school (m)*)	2.858	1.194	0	5.446	2.996	1.261	0	5.320
ln (*Bus stop (m)*)	1.535	1.173	0	4.579	1.863	1.261	0	4.979
ln (*Golf course*)	3.538	0.877	0	5.690	3.822	0.911	0	5.648
ln (*Transitional water body*)	3.763	1.622	0	6.399	3.767	1.624	0	6.155
ln (*Centres of population*)	2.361	0.992	0	4.514	2.193	0.989	0	4.500
ln (*Galway City parks*)	6.374	1.959	0	7.851	7.003	0.835	1.402	7.841
ln (*Garda station*)	2.697	1.074	0	5.260	2.737	1.129	0	4.964
ln (*Glenveagh national park*)	7.392	0.975	0	8.264	7.476	0.964	1.554	8.237
ln (*Lakes and reservoirs*)	4.498	1.147	0	6.339	4.895	0.866	0	6.186
ln (*Cliffs*)sea_floor_and_w	4.741	1.094	0	6.499	4.530	1.209	0	6.391
ln (*Rivers*)	1.100	0.846	0	4.202	1.308	1.124	0	3.944
ln (*Coniferous or mixed forest*)	2.944	0.876	0	5.100	3.041	0.930	0	4.733
ln (*Broadleaf forest*)	3.496	1.132	0	6.146	3.435	0.995	0	5.913
ln (*Beaches, dunes, and sands*)	5.232	0.947	0	6.674	5.077	1.086	0	6.535
Turbine related	mean	sd	min	max	mean	sd	min	max
Distance to nearest turbine (m)	9,798	2,887	5,000	15,000	3,490	1,014	123.7	4,999
Hub height	69.43	18.29	33	100	75.23	21.88	33	100
Rotor diameter	73.93	20.58	31	117	78.57	22.65	31	117
Turbine height	106.4	27.81	48.50	152	114.5	32.66	48.50	152
ln (*Inverse distance to turbine (m)*)					0.417	0.377	0.000155	3.699
Weighted density					0.422	0.951	0.04	26.494
Nearest turbine <1,000m					0.0178	(0.132)		
Nearest turbine 1000m-1999m					0.0698	(0.255)	0	1
Nearest turbine 2000m-2999m					0.223	(0.416)	0	1
Nearest turbine 3000m-3999m					0.336	(0.472)	0	1
Nearest turbine 4000m-4999m					0.354	(0.478)	0	1

Appendix 1: Full summary statistics

	Dependent variable: ln(*Listed house price*(€))					
	(1) Naieve	(2) + Simple housing	(3) + Detailed housing	(4) + Man made amenities	(5) + Water amenities	(6) *All controls* + Natural amenities
VARIABLES						
ln(*Inverse wind turbine distance*)	-0.024	-0.051*	-0.058**	-0.060***	-0.062**	-0.057**
	(0.042)	(0.027)	(0.023)	(0.022)	(0.024)	(0.025)
Bedrooms = 1		-0.149***	-0.133***	-0.134***	-0.139***	-0.139***
		(0.022)	(0.021)	(0.021)	(0.021)	(0.021)
Bedrooms = 2 (Base)						
Bedrooms = 3		0.132***	0.123***	0.123***	0.125***	0.125***
		(0.011)	(0.011)	(0.010)	(0.010)	(0.010)
Bedrooms = 4		0.227***	0.206***	0.207***	0.209***	0.209***
		(0.013)	(0.012)	(0.012)	(0.012)	(0.012)
Bedrooms = 5		0.294***	0.263***	0.263***	0.265***	0.265***
		(0.015)	(0.014)	(0.014)	(0.013)	(0.013)
Bathrooms = 1		-0.173***	-0.143***	-0.143***	-0.142***	-0.142***
		(0.007)	(0.006)	(0.006)	(0.006)	(0.006)
Bathrooms = 2 (Base)						
Bathrooms = 3		0.056***	0.045***	0.045***	0.047***	0.047***
		(0.006)	(0.005)	(0.005)	(0.005)	(0.005)
Bathrooms = 4		0.118***	0.096***	0.096***	0.096***	0.096***
		(0.014)	(0.012)	(0.012)	(0.012)	(0.012)
Bathrooms = 5		0.206***	0.165***	0.165***	0.166***	0.166***
		(0.021)	(0.018)	(0.018)	(0.018)	(0.018)
Bathrooms = 6		0.309***	0.225***	0.226***	0.223***	0.222***
		(0.036)	(0.031)	(0.031)	(0.031)	(0.031)
Bathrooms = 7		0.459***	0.355**	0.359**	0.371***	0.371***
		(0.172)	(0.141)	(0.140)	(0.136)	(0.136)
Bathrooms = 8		0.631***	0.653***	0.666***	0.650***	0.649***
		(0.117)	(0.103)	(0.102)	(0.114)	(0.116)
Floor area (m^2) missing		0.072***	0.065***	0.066***	0.066***	0.066***
		(0.010)	(0.009)	(0.009)	(0.009)	(0.009)
Floor area (m^2)0.1-49.9		-0.048	-0.052*	-0.050*	-0.054*	-0.054*
		(0.034)	(0.030)	(0.030)	(0.030)	(0.030)
Floor area (m^2) $\leq$70(Base)						
Floor area (m^2)$\leq$82		0.043***	0.040***	0.040***	0.040***	0.040***
		(0.011)	(0.010)	(0.010)	(0.010)	(0.010)
Floor area (m^2) $\leq$93		0.042***	0.040***	0.041***	0.042***	0.042***
		(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
Floor area (m^2) $\leq$103		0.060***	0.051***	0.052***	0.050***	0.050***
		(0.011)	(0.010)	(0.010)	(0.010)	(0.010)
Floor area (m^2) $\leq$115		0.083***	0.067***	0.069***	0.069***	0.068***
		(0.012)	(0.011)	(0.011)	(0.011)	(0.011)
Floor area (m^2) $\leq$130		0.111***	0.090***	0.092***	0.091***	0.091***
		(0.012)	(0.012)	(0.012)	(0.012)	(0.012)
Floor area (m^2) $\leq$153.1		0.153***	0.123***	0.124***	0.121***	0.120***
		(0.013)	(0.011)	(0.011)	(0.011)	(0.011)
Floor area (m^2) $\leq$196.8		0.218***	0.170***	0.171***	0.168***	0.167***
		(0.014)	(0.013)	(0.013)	(0.013)	(0.013)
Floor area (m^2) $\leq$400		0.362***	0.277***	0.277***	0.273***	0.272***
		(0.016)	(0.014)	(0.014)	(0.014)	(0.014)
Floor area (m^2) $\leq$10000		0.285***	0.226***	0.226***	0.222***	0.221***
		(0.034)	(0.029)	(0.029)	(0.028)	(0.028)
Acres 0		-0.084***	-0.048**	-0.044**	-0.052***	-0.053***
		(0.021)	(0.019)	(0.019)	(0.020)	(0.020)
Acres 0-0.5		-0.019	-0.015	-0.011	-0.013	-0.014
		(0.024)	(0.022)	(0.022)	(0.023)	(0.023)
Acres 0.5-1(Base)						
Acres 1-2		0.133***	0.097**	0.098**	0.084**	0.084**
		(0.045)	(0.039)	(0.039)	(0.038)	(0.038)
Acres 2-5		0.233***	0.189***	0.190***	0.174***	0.176***
		(0.058)	(0.054)	(0.053)	(0.055)	(0.055)
Acres 5-10		0.272***	0.225***	0.223***	0.216***	0.216***
		(0.071)	(0.061)	(0.061)	(0.060)	(0.059)
Acres 10-20		0.314***	0.333***	0.333***	0.314***	0.315***
		(0.076)	(0.072)	(0.072)	(0.069)	(0.069)
Acres 20-50		0.418***	0.369**	0.371**	0.374**	0.372**
		(0.118)	(0.160)	(0.156)	(0.153)	(0.153)
Acres >50		0.969***	1.045***	1.046***	1.019***	1.021***
		(0.210)	(0.197)	(0.196)	(0.199)	(0.198)
Appartment (Base)						
Bungalow		0.451***	0.375***	0.367***	0.376***	0.376***
		(0.022)	(0.021)	(0.022)	(0.021)	(0.021)
Duplex		-0.018	-0.031	-0.034*	-0.030	-0.030
		(0.022)	(0.020)	(0.020)	(0.020)	(0.020)
House		0.458***	0.384***	0.376***	0.385***	0.385***
		(0.023)	(0.022)	(0.022)	(0.022)	(0.022)
Site		-0.165	-0.106	-0.113	-0.116	-0.116
		(0.132)	(0.128)	(0.128)	(0.127)	(0.127)
Studio		-0.082	-0.082	-0.090	-0.094	-0.094
		(0.108)	(0.108)	(0.108)	(0.103)	(0.102)

	Dependent variable: ln(*Listed house price*(€))					
	(1) Naieve	(2) + Simple housing	(3) + Detailed housing	(4) + Man made amenities	(5) + Water amenities	(6) *All controls* + Natural amenities
VARIABLES						
Detatched (Base)						
End-of-terrace		-0.341***	-0.296***	-0.289***	-0.291***	-0.291***
		(0.013)	(0.012)	(0.013)	(0.012)	(0.012)
Semi-detached		-0.268***	-0.244***	-0.239***	-0.237***	-0.238***
		(0.010)	(0.010)	(0.010)	(0.010)	(0.010)
Terraced		-0.415***	-0.364***	-0.356***	-0.359***	-0.359***
		(0.013)	(0.012)	(0.012)	(0.012)	(0.012)
Townhouse		-0.372***	-0.325***	-0.317***	-0.322***	-0.322***
		(0.021)	(0.018)	(0.018)	(0.017)	(0.017)
BER code A1 (Base)						
Ber code A2		0.002	-0.010	-0.008	-0.006	-0.009
		(0.035)	(0.047)	(0.046)	(0.043)	(0.043)
Ber code A3		-0.062*	-0.102**	-0.100**	-0.094**	-0.097**
		(0.036)	(0.046)	(0.045)	(0.043)	(0.043)
Ber code B1		-0.006	-0.134**	-0.135**	-0.134***	-0.137***
		(0.045)	(0.053)	(0.053)	(0.050)	(0.050)
Ber code B2		-0.098***	-0.216***	-0.218***	-0.216***	-0.217***
		(0.035)	(0.045)	(0.044)	(0.042)	(0.042)
Ber code B3		-0.138***	-0.251***	-0.253***	-0.250***	-0.252***
		(0.033)	(0.045)	(0.044)	(0.041)	(0.041)
Ber code C1		-0.191***	-0.279***	-0.280***	-0.278***	-0.280***
		(0.033)	(0.045)	(0.044)	(0.041)	(0.041)
Ber code C2		-0.217***	-0.304***	-0.305***	-0.305***	-0.306***
		(0.033)	(0.044)	(0.043)	(0.040)	(0.041)
Ber code C3		-0.231***	-0.312***	-0.312***	-0.314***	-0.316***
		(0.033)	(0.044)	(0.043)	(0.041)	(0.041)
Ber code D1		-0.271***	-0.350***	-0.350***	-0.352***	-0.353***
		(0.034)	(0.045)	(0.044)	(0.041)	(0.041)
Ber code D2		-0.281***	-0.360***	-0.360***	-0.363***	-0.365***
		(0.034)	(0.045)	(0.044)	(0.041)	(0.041)
Ber code E1		-0.315***	-0.391***	-0.392***	-0.396***	-0.397***
		(0.034)	(0.045)	(0.044)	(0.041)	(0.042)
Ber code E2		-0.353***	-0.430***	-0.430***	-0.434***	-0.436***
		(0.034)	(0.045)	(0.044)	(0.041)	(0.041)
Ber code Exempt		-0.375***	-0.439***	-0.441***	-0.444***	-0.446***
		(0.054)	(0.055)	(0.054)	(0.051)	(0.051)
Ber code F		-0.375***	-0.444***	-0.445***	-0.447***	-0.449***
		(0.035)	(0.046)	(0.045)	(0.042)	(0.042)
Ber code G		-0.537***	-0.586***	-0.586***	-0.592***	-0.594***
		(0.035)	(0.045)	(0.044)	(0.041)	(0.042)
Ber code Unknown		-0.312***	-0.373***	-0.373***	-0.374***	-0.376***
		(0.033)	(0.044)	(0.043)	(0.040)	(0.040)
Cities		0.151***	0.165***	0.169***	0.140***	0.143***
		(0.033)	(0.031)	(0.032)	(0.033)	(0.032)
Satellite towns (Base)		0.043	0.070**	0.071**	0.096***	0.096***
		(0.032)	(0.032)	(0.032)	(0.035)	(0.035)
Independent urban towns		-0.030	-0.013	-0.007	0.005	0.001
		(0.028)	(0.029)	(0.030)	(0.030)	(0.030)
Rural areas with high urban influence		0.052*	0.059**	0.056**	0.070***	0.067***
		(0.027)	(0.026)	(0.025)	(0.025)	(0.025)
Rural areas with moderate urban influence		0.034*	0.037**	0.037**	0.045***	0.043***
		(0.028)	(0.029)	(0.029)	(0.032)	(0.032))
Highly rural/remote areas (Base)						
South = 1			0.031***	0.030***	0.028***	0.028***
			(0.006)	(0.006)	(0.006)	(0.006)
West = 1			0.013*	0.013*	0.012	0.012
			(0.008)	(0.008)	(0.008)	(0.008)
Southwest = 1			0.006	0.006	0.009	0.009
			(0.014)	(0.014)	(0.013)	(0.013)
Balcony = 1			0.087***	0.086***	0.076***	0.076***
			(0.012)	(0.012)	(0.011)	(0.011)
Period = 1			0.188***	0.189***	0.180***	0.180***
			(0.024)	(0.024)	(0.023)	(0.023)
Victorian = 1			0.204***	0.203***	0.196***	0.198***
			(0.043)	(0.043)	(0.043)	(0.043)
Georgian = 1			0.154***	0.155***	0.145***	0.144***
			(0.045)	(0.045)	(0.045)	(0.045)
Edwardian = 1			0.234***	0.231***	0.230***	0.231***
			(0.077)	(0.078)	(0.078)	(0.078)
Baywindow = 1			0.022***	0.022***	0.022***	0.022***
			(0.006)	(0.006)	(0.006)	(0.006)
Corner house = 1			-0.048**	-0.047**	-0.047**	-0.047**
			(0.024)	(0.023)	(0.022)	(0.022)
Utility = 1			0.059***	0.060***	0.058***	0.059***
			(0.005)	(0.005)	(0.005)	(0.005)
Conservatory = 1			0.078***	0.077***	0.078***	0.078***
			(0.007)	(0.007)	(0.007)	(0.007)
Granny flat = 1			0.071***	0.070***	0.069***	0.069***
			(0.019)	(0.020)	(0.019)	(0.019)
Culdesac = 1			0.004	0.004	0.003	0.003
			(0.006)	(0.006)	(0.006)	(0.006)
Jacuzzi = 1			0.055***	0.054***	0.054***	0.054***
			(0.009)	(0.010)	(0.009)	(0.009)
Wardrobef = 1			0.018***	0.018***	0.018***	0.018***
			(0.005)	(0.005)	(0.005)	(0.005)
Wardrobew = 1			0.042***	0.041***	0.041***	0.040***
			(0.008)	(0.008)	(0.008)	(0.008)
Wetroom = 1			0.052***	0.053***	0.053***	0.052***
			(0.010)	(0.010)	(0.010)	(0.010)
Underfloor = 1			0.112***	0.112***	0.110***	0.110***
			(0.015)	(0.015)	(0.015)	(0.014)
Ensuite = 1			0.024***	0.024***	0.024***	0.024***
			(0.005)	(0.005)	(0.004)	(0.004)

	Dependent variable: ln(*Listed house price*(€))					
	(1)	(2)	(3)	(4)	(5)	(6) *All controls*
	Naieve	+ Simple housing	+ Detailed housing	+ Man made amenities	+ Water amenities	+ Natural amenities
VARIABLES						
Fireplace = 1			0.043***	0.043***	0.044***	0.043***
			(0.004)	(0.004)	(0.004)	(0.004)
Stove = 1			0.081***	0.080***	0.080***	0.081***
			(0.005)	(0.005)	(0.005)	(0.005)
Aga = 1			0.074***	0.073***	0.073***	0.073***
			(0.010)	(0.010)	(0.009)	(0.009)
Burner = 1			0.042	0.040	0.035	0.035
			(0.032)	(0.032)	(0.032)	(0.032)
Solarpanel = 1			0.001	0.001	0.007	0.007
			(0.013)	(0.013)	(0.012)	(0.012)
Garden = 1			0.037***	0.038***	0.039***	0.039***
			(0.005)	(0.005)	(0.005)	(0.005)
Garage = 1			0.100***	0.098***	0.098***	0.098***
			(0.005)	(0.005)	(0.005)	(0.005)
Frenchdoors = 1			0.033***	0.033***	0.031***	0.031***
			(0.007)	(0.007)	(0.007)	(0.007)
Highceiling = 1			0.080***	0.082***	0.077***	0.078***
			(0.018)	(0.018)	(0.018)	(0.017)
Corniced = 1			0.038***	0.038***	0.037***	0.038***
			(0.012)	(0.012)	(0.012)	(0.012)
Refurb = 1			0.087***	0.086***	0.083***	0.083***
			(0.007)	(0.007)	(0.007)	(0.007)
Double glaze = 1			0.004	0.004	0.004	0.004
			(0.006)	(0.006)	(0.006)	(0.006)
PVC = 1			-0.017***	-0.017***	-0.016***	-0.016***
			(0.005)	(0.005)	(0.005)	(0.005)
PVCu = 1			0.034**	0.034**	0.035**	0.035**
			(0.016)	(0.016)	(0.017)	(0.017)
Brands = 1			0.080***	0.081***	0.079***	0.078***
			(0.018)	(0.017)	(0.017)	(0.017)
ln (*Golf course*)				-0.019**	-0.011	-0.010
				(0.009)	(0.009)	(0.008)
ln (*Galway City parks*)				-0.006	0.012	0.011
				(0.026)	(0.023)	(0.023)
ln (*Garda Stations*)				-0.006	-0.004	-0.003
				(0.009)	(0.008)	(0.008)
ln (*Motorway access*)				0.449	-0.259	-0.264
				(0.380)	(0.317)	(0.321)
ln (*Railway station*)				-0.005	-0.014	-0.014
				(0.020)	(0.020)	(0.020)
ln (*Settlements*)				0.005	0.009*	0.010*
				(0.005)	(0.005)	(0.005)
ln (*Primary school*)				0.003	-0.001	-0.000
				(0.005)	(0.005)	(0.005)
ln (*Secondary school*)				-0.007	-0.005	-0.004
				(0.008)	(0.007)	(0.007)
ln (*Bus stop*)				0.015**	0.020***	0.020***
				(0.006)	(0.006)	(0.006)
ln (*Coast*)					-0.064***	-0.062***
					(0.012)	(0.011)
ln (*Transitional waters*)					-0.040***	-0.039***
					(0.008)	(0.008)
ln (*Lakes or reservoirs*)					-0.045***	-0.043***
					(0.011)	(0.011)
ln (*Rivers*)					0.007	0.007
					(0.005)	(0.005)
ln (*Cliffs*)					-0.027	-0.026
					(0.016)	(0.016)
ln (*Beaches, Dunes, or Sands*)					-0.003	-0.005
					(0.013)	(0.013)
ln (*300m contour line*)						0.002
						(0.013)
ln (*Nature reserve*)						-0.026
						(0.021)
ln (*Coniferous or mixed*)						0.012*
						(0.006)
ln (*Broadleaf*)						-0.009
						(0.006)
ED fixed effects	Y	Y	Y	Y	Y	Y
Year and quarter fixed effects	Y	Y	Y	Y	Y	Y
Constant	11.873***	11.702***	11.677***	8.563***	14.317***	14.455***
	(0.011)	(0.047)	(0.054)	(2.670)	(2.239)	(2.299)
Observations	64,136	64,136	64,136	64,136	64,136	64,136
R-squared	0.022	0.518	0.563	0.564	0.570	0.571
Number of ed_id_encrypted	962	962	962	962	962	962

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Appendix 2: Sensitivity analysis from naive model to all controls model.