The Effect of Undesirable Land Use Facilities on Property Values: New Evidence from Australian Regional Fossil-Fired Plants

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Abstract

This paper investigates the effect of fossil-fired power plants on the value of neighborhood properties in the state of New South Wales, Australia. Fossil-fuels accounts for significant proportion of electricity generation in Australia. Thus, there are growing community concerns regarding the possible negative environmental effects of these power plants given the high level of emission produced by these plants. We use a comprehensive data with the exact location of each property to estimate the effect of an existing fossil-fuel power plant on the value of neighborhood properties. We use spatial econometric models to estimate these effects with controls over several characteristics of properties. Our results suggest that coal-fired power plants have significant negative effects on property values within a specific radius. These effects are less but still negative for gas and gas reciprocating power plants.

Keywords: Fossil-fired; power plants; emissions; property price.

JEL Classification: Q51, Q53, R11, R30.

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1 Introduction

Fossil fuels are the world's most important source of energy mainly due to their reliability, abundance and relatively cheap prices. They deliver direct economic benefits to local communities and provide a low-cost and reliable source of energy in sustaining economic growth. While forty percent of world's total electricity production is derived from the combustion of coal, the number of fossil-fuel power plants is expected to increase in the next two-decades as the global demand for energy increases IEA (2012). However, fossil-fired power plants are a clear source of potential global environmental costs since they are one of the biggest contributors of greenhouse gas emissions across both developing and developed countries[1] and also responsible for greater depletion of natural energy resources. This is particularly so in the case of large fossil-fired power plants sites that are optimal in terms of energy efficiency and are typically located in rural, coastal and wilderness locations that offers many natural environmental amenities. These natural amenities can include the aesthetic appeal of landscape, outdoor recreational opportunities and the existence values of wilderness habitats and biodiversity (Gibbons (2015)).

However, the end-user energy price does not reflect the 'external costs' of electricity generation from fossil-fuels which can be big burdens to the society especially in terms of adverse health impacts on the population. Around 95 percent of the total external costs consist of the adverse health impacts (Markandya and Wilkinson (2007)). In Europe, the health cost of air pollution from fossil-fired power stations was estimated at 43 billion Euros a year (HEAL, 2013). In the US, economists have estimated the health impacts of coal-fired power stations to be between one and six times its value added (Parkinson (2014)). In Australia, it is estimated that the adverse health impacts from pollutants produced from coal-fired electricity generation costs AU \$2.6 billion annually (Climate-Council (2014)). These health costs can, to some extent, translate into negative economic costs by adversely affecting the value of the surrounding properties.

Australia, in particular, has been dominantly relying on fossil-fuel electricity since history permits and has the highest per capita emissions among the OECD economies. The nation is a major user as well as exporter of coal, particularly from the New South Wales (NSW), a fact well reflected in the state's energy generation mix. Black coal sourced around 65 percent of electricity generation in NSW in 2015 while coal provides about 69 percent of Australia's electricity. Almost 90 percent of Australia's coal based electricity generation is from the most polluting sub-critical coal-fired power stations (SCPSs).[2]

[1] They are the sources of particulate matter, sulfur dioxide and oxides of nitrogen.

[2] SCPSs are the most polluting because of their use of sub-critical boilers while the majority of the SCPSs are much older exceeding over 30 years of operation on average. For example, the more than 50 years old Hazel-wood coal-fired power station in Victoria was identified as the least carbon-efficient power station in

As a consequence, emissions in NSW amounted to 142 million tonnes of carbon dioxide (CO2) —around 26 percent of Australia's total emissions— with stationary energy (primarily from electricity generation) contributing around 50 percent of NSW emissions during 2012/2013 (NSW-Government, 2012).

Now, there is a growing community concern and public opposition to numerous negative local externalities such as ambient air quality and local amenity risks including adverse health and economic impacts associated with particulate matter emissions from fossil-fuel burning in NSW (NSW-EPA, 2016). A recently published Harvard scholarly report by Ward and Power (2015) has escalated this view by estimating that the Hazel-wood coal-fired plant in the state of Victoria (VIC) annually imposes an economic cost of 900 million dollars to Australians including damages to properties. These environmental concerns are likely to increase with increasing population and rising electricity demand in NSW in the absence of any policy interventions such as a carbon price, ambitious renewable energy targets, and cap-and-trade markets unlike other developed countries.[3] For instance, the existence of a cap-and-trade market would potentially help the regulator to not only reduce the emission but also compensate those who are affected by the pollution.

However, empirical evidence on the direct impacts of fossil-fuels incineration to property prices and value of other vulnerable assets does not exist in the NSW and Australia, which indicates a major research gap. This is the first paper to provide quantitative evidence on the local costs of fossil-fuel power plants development and operations in regional NSW, focusing on the effects of coal-fired, gas-turbine and gas-reciprocal power plant locations, and their implied costs in terms of loss of visual landscape, economic and health amenities. We rely on housing sales prices to reveal local preferences for the existence of power stations in line with the well-established tradition and literature of hedonic studies in environmental, public and urban economics. The negative externalities impact of fossil-fired plants (coal, gas-turbine and reciprocal power plants) on price response using evidence from the NSW housing market are examined given that the adjacent property markets are most likely impacted markets due to the health and local amenity risks originating from the environmental hazards.

In line with economic theory, our hypothesis is that residents and buyers are aware of air pollution and the associated health and amenity risks. Therefore, their combined effect on property prices implying that properties closer to the power plants have lower prices than those that are further away. We test these claims using a unique and previously

the OECD.

[3]In countries such as the United States and China coal accounts for a large amount of the pollution. Indeed, in the US, coal generates around 44 percent of the electricity but it is still the biggest air polluter. However, in the US there are different cap-and-trade markets for emissions in many states, which make their case a bit different to Australia.

untested data-set of the Australian housing market. We used a data-set with more than 100,000 observations, which includes one of the most precise information one needs for the current analysis. In particular, apart from detailed characteristics of each property, we observe the exact location of each property with longitudes and latitudes. Therefore, we are able to identify the distance of each property from the closest power plant. Given this comprehensive data we use spatial econometric models to estimate the effect of being close to a power plant on value of properties.

The results suggest that the values of properties in the vicinity of a power plant could be affected negatively within up to 30km radius. This effect is the most for coal-fired power plants which indicates in some cases up to 27.8% decrease in the value of properties within 30km radius. The results for gas power plants also shows negative effects on the neighborhood properties but the negative effects vanish at up to 20km radius. Finally, gas reciprocal power plants have the least price discount for properties in their neighborhood which is less than 5% for all of the models we estimated.

The contributions of this research are as follows. This is the first systematic study in the Australian context to directly quantify the impacts of fossil-fired electricity generation plants and their locations on the housing market. The findings have broader implications for energy and environmental policy-making since Australia heavily relies on fossil-fired plants to meet its electricity demand. Understanding the local amenity impacts of gas generation is very important from an energy and environmental policy perspective since gas acts as the facilitating fuel in the global transition towards a low carbon economy since it sits between 'coal' and 'renewables'. This study is also relevant to an extensive set of earlier literature examining the impact of undesirable land-use facilities such as coal-fired power plants and property values as summarized in Farber (1998) and Davis (2011). However, this is the first large-scale study of fossil-fired electricity generation plants in the context of a fossil fuel rich and fossil fuel-dependent economy which also includes gas-turbine and gas reciprocal generation plants. The third important contribution of this study is in the analytical framework as we differ from earlier studies by using two variations of spatial models. We have quantified the effects of power plants on neighborhood properties with the changes of distance and showed these effects varies with the distance as well as the power plant type.

The rest of the paper is organized as follows. Section 2 provides a background review on the local impacts of fossil-fired power plants with a summary of the relevant literature. The analytical framework based on hedonic price model is described in section 3. Section 4 discusses the data in detail with further explanation of the methods used for extracting the exact locations. Section 5 presents and discusses the results. Finally, in Section 6 we conclude the study and provide suggestions for relevant policy implications of the current study.

2 Earlier Studies

Economic principle suggests that the perceived or real location-specific adverse amenity effects of certain types of land use such as fossil-fired electricity generation are incorporated in location-related markets such as housing as households would be willing to pay to reside where such risks are lower under conditions of adequate information (Freeman (1979); Fischer *et al.* (1991)). A power plant affects property values because households consider it a nuisance and requires compensation for coping with its undesirable effects ((Blomquist, 1974)). Hence, people express a willingness to pay to avoid concerns about the environmental risks or nuisances. When property buyers value these risks, then property prices should experience a decline in the immediate vicinity of the plants while property buyers should sort themselves in across neighborhood based on their willingness-to-pay to avoid owning property nearby a fossil-fired generation plant.

An earlier studied by Farber (1998) summarized the empirical studies to examine whether undesirable land use, including the location of power plants, has negative effects on property values. Only few systematic studies have been pursued since then that examines the impacts of power plants on neighborhood property prices. The impacts of nuclear power plants on property prices have received the most attention among these and mostly in the US context but are beyond the objective of the paper to discuss those studies in depth. The findings by Clark *et al.* (1997) showed no support to the contention that visual dis-amenity surrounding nuclear power plants or stored nuclear waste has a significant negative influence on residential home prices in the immediate vicinity of these facilities. Folland and Hough (2000) examined the effects of nuclear power plants on property values by assembling a large panel data covering the span from 1945 to 1992. They found that the preponderance of significant, negative estimated effects strongly suggested a negative nuclear externality and one that appears throughout the major portion of the nuclear era. Likewise, Olsen and Wolff (2013) found that housing values around 10 miles of the nuclear plants decreased with plant placement and increased with plant closures while the 1986 Chernobyl nuclear accident in the Ukraine served as an information shock to US residents between 1970-2000.

Most notably, a recent study by Davis (2011), using large-scale evidence from electricity generation plants (including coal-fired plants) showed that compared to neighborhoods with similar housing and demographic characteristics, neighborhoods within 2 miles of plants experienced 3-7% decreases in housing values and rents compared to neighborhoods with similar housing and demographic characteristics, with some evidence of larger decreases within 1 mile and for large-capacity plants. Another interesting study by Gibbons (2015) valued the visual impacts of wind turbines through house prices using large samples of housing sales in the context of England and Wales. The results showed that price reduction is around 5-6% for housing with a visible wind farm of average size (11 turbines) within 2km, falling to 3% within 4km, and to 1% or less by 14km, which is at the limit of likely visibility.

In the Australian context, the study by Neelawala *et al.* (2013) stands out although they examine the impact of mining and smelting activities on property prices in the regional Queensland town of Mount Isa. Their results show that marginal willingness to pay to be farther from the pollution source is AU$7,514 per kilometer within the four km radius selected. Similarly, another study Neelawala *et al.* (2015) examined the property value impacts of an announcement of a project with potential environmental impacts. The results of the study confirm that the marginal willingness to pay for properties within a 5 km distance declined by AU$17,020 per km proximity to the proposed heavy vehicle route, after the proposed route was announced.

Hence, it is clear from the literature review that only few studies have focused on fossil-fired plants even though a large number of studies have been conducted to demonstrate the impact of environmental aspects on property prices leaving the literature incomplete. This is the first systematic study in the context of a high emitting economy to investigate of the impact of fossil-fired electricity generation on residential property prices to the best of our knowledge. Therefore, this study contributes to an important and highly relevant topic in the environmental economics and housing prices literature.

3 Methodology

The hedonic model has been commonly used in property price estimation. This model explains that values of various attributes of heterogeneous goods are reflected in price differentials; therefore, the price of the residential property can be valued based on structural, neighborhood, and environmental characteristics. This method has an advantage over other estimation techniques as it uses actual market transactions to recover value estimates for non-market attributes. In our model we use structural characteristics of properties such as number of bedrooms, bathrooms, swimming pools, and neighborhood and environmental characteristics using several proximity measures such as distance to school, shops, rivers and the ocean. We measure the effect of externality effect of power plants using a distance measure. In addition, we use socio-economic variables to measure the locality differences. The model is specified in the following equation.

$$y_i = \beta_0 + \sum_{q=1}^{q} \theta_q D_{iq} + \sum_{k=1}^{k} \beta_k X_{ik} + \sum_{c=1}^{c} \gamma_c S_{cl} + \sum_{p=1}^{3} \alpha_p D_{ip} + \epsilon_i, \quad (1)$$

where, $y_i = ln(\text{sale price } i)$, for $i = 1, ..., N$, D_{iq} time dummy for properties sold in quarter q, X is the k_i value of the k^{th} hedonic characteristics and environmental variables for property i. S_{cl} value of the c^{th} socio-economic characteristic in each suburb l. These variables are discussed in Section 4.

Hedonic models are usually estimated in linear or log-linear (semi-log) forms. We estimated the model in log-linear specification which has advantages in terms of interpretation. In the log-linear form, the coefficients can be easily interpreted as the proportional change in the price given a one-unit change in the characteristic. This allows us to interpret the effects of power plants as a percentage impact on the value of a property.

Since spatial nature of properties is also important to study the property values, we use spatial econometric model for our estimation. LeSage and Pace (2009) provides a comprehensive review of spatial econometric models that are applicable to hedonic models. We estimated two spatial variation of the models, a spatial error model (SEM) and a spatial Durbin model (SDM), (Rambaldi *et al.*, 2014).

The SEM model assumes that any spatial dependence from omitted characteristics is captured through unobserved component of the model, ϵ_i. The SEM model for Equation (1) can be written as,

$$\epsilon_i = \rho \sum_{j=1}^{N} w_{ij}\epsilon + u_i, \tag{2}$$

where $u_i \sim N(0, \sigma^2)$.

ϵ_i is a spatially correlated error and $0 \leq \rho < 1$, is a spatial correlation parameter. $0 \leq w_{ij} \leq 1$ ($\sum_{j=1}^{N} w_{ij} = 1$) is the weight of property j on property i based on their distance calculated using a Delaunay triangulation. w_{ij} is, therefore, the element of the stochastic spatial weight matrix W. To construct the spatial weight matrix, a measure on the nearest neighborhood is calculated using Delaunary triangulation (see LeSage and Pace (2009) sec. 4.11). The SDM can be written as,

$$\begin{aligned} y_i = \beta_0 &+ \lambda \sum_{j=1}^{N} w_{ij} y_i + \sum_{q=1}^{3} \theta_q D_{iq} + \sum_{q=1}^{3} \delta_q \sum_{j=1}^{N} (w_{ij})_{iq} D_{iq} + \sum_{k=1}^{k} \beta_k X_{ik} \\ &+ \sum_{k=1}^{k} \tau_k \sum_{j=1}^{N} w_{ij} X_{ik} + \sum_{c=1}^{c} \gamma_c S_{cl} + \sum_{c=1}^{c} \varphi_c \sum_{j=1}^{N} w_{ij} S_{cl} + \sum_{p=1}^{3} \alpha_p D_{ip} \\ &+ \sum_{p=1}^{3} \omega_p \sum_{j=1}^{N} (w_{ij})_{ip} D_{ip} + \sum_{p=1}^{3} \vartheta_p Z_{ip} D_{ip} + \sum_{p=1}^{3} \pi_p \sum_{j=1}^{N} (w_{ij})_{ip} Z_{ip} D_{ip} + \epsilon_i \end{aligned} \tag{3}$$

where λ is the spatial parameter. The regressors in the above specification appear in two forms i.e. independently and as variables interacted with the spatial weight matrix. Hence, the marginal effects of each variable consist of two parameters: β and τ for each hedonic characteristic X; γ and φ for each socio-economic variable S in postcode l; and $delta$ and θ for each quarterly dummy. α and ω parameter estimates for dummies used for type of power plant p and ϑ and π are for their slope parameters. Therefore, the slope of the log-linear function is not the coefficient estimates as in other conventional models; it should be calculated using these two coefficient estimates from SDM. The slope of the average direct effect for each variable is calculated as LeSage and Pace (2009) as follows.

$$N^{-1} trace[S_k(W)] \text{ and } \frac{dy_i}{dx_{jk}} = S_k(W)_{ij} \tag{4}$$

The average value of direct impact associated with all observation i is similar to the conventional regression coefficient.

4 Data

The data for the current study is divided into four major sources. First, we have the data on all residential properties sold in the state on New South Wales, Australia, during the calendar year 2011. This data is collected and provided by the Australian Property Monitors.[4] Specifically, we observe 102,846 sold properties during this time, which includes the date properties were sold, transaction prices and several property characteristics for every observation. These characteristics include the number of bedrooms, bathrooms, car-park and pool which provide detailed hedonic characteristics for each property. We also observe the exact location of each property with the exact longitude and latitude. The age of property structure could be an important determinant of house prices; however, the data are not readily available. Some studies collected these information using extensive search with the aid of variety of tools such as Google street view, additional information from local councils, expert knowledge of the relationship between age and appearance of each property, building materials (Rambaldi *et al.* (2013); Rambaldi *et al.* (2014)). However, we were not able to carry out such a detailed extensive data search for a data set with over 100,000 transactions of properties. Also, there are many properties with older structures that went under significant renovation and therefore, the age of the structure by itself could not represent the actual value of a property. However, we assume to detect this sort of omitted spatial characteristics through the unobserved component, considering it as a spatial dependence of the SEM model.

[4] The sources of the data are mainly the New South Wales government and the real estate agents.

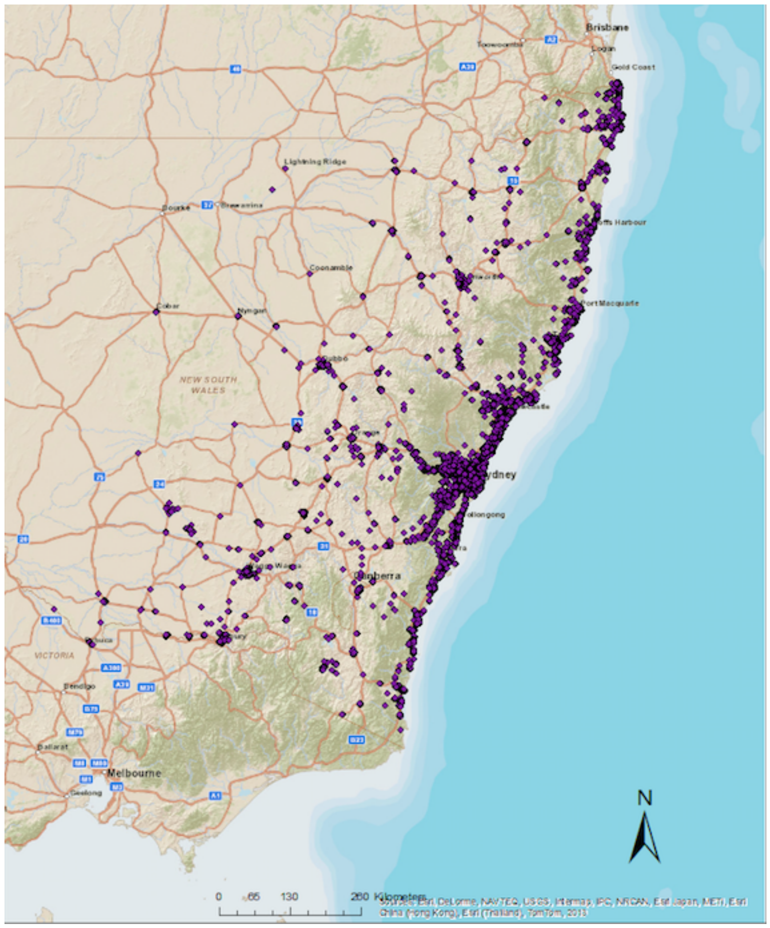
Table 1: Summary Statistics

Variables	Mean	Median	Max.	Min.	St. Dev.
Transaction price (AU$)	570,264	446,500	18,500,000	165,000	502,823
Home characteristics					
Property type (House = 1, Unit = 0)	0.73	1	1	0	0.44
Number of bedrooms	3.11	3	8	0	1.12
Number of bathrooms	1.57	1	8	1	0.69
Number of car parks	1.50	1	12	0	0.88
Has pool	0.06	0	1	0	0.25
Has fireplace	0.06	0	1	0	0.23
Dist. (KMs)					
Dist. to coal power plant†	129	100	975	0.67	115
Dist. to gas power plant†	72.3	28.8	774	0.57	125
Dist. to gas reciprocating power plant†					
Dist. to coastline	35.8	11.2	670	0.00	74.8
Dist. to waterway	1.59	1.05	84.1	0.00	2.61
Dist. to streams	3.63	1.85	131	0.00	8.12
Dist. to train stn.	6.13	2.18	165	0.00	13.5
Dist. to railway	6.20	1.63	198	0.00	16.8
Dist. to schools	1.01	0.75	47.9	0.00	1.40
Dist. to river	12.4	5.03	369	0.00	25.8
Dist. to industry	11.1	2.67	382	0.00	26.4
Dist. to hospitals	9.33	4.83	223	0.05	15.4
Dist. to shops	5.44	1.87	308	0.00	16.7
Dist. to park	5.11	3.56	99.9	0.00	6.91
Dist. to water	3.24	1.89	159	0.00	6.63
Dist. to City Hall	109.8	35.1	1117	0.24	168
Neighbourhood characteristics‡					
Mean household income (AU$)	60,168	53,615	176,396	34,641	18,908
Population	26,093	23,096	95,041	594	17,099
Median weekly rent (AU$)	336	320	780	100	104.5
Number of dwellings	10,617	9,571	32,922	155	6,445
Mean Number of vehicle	1.59	1.6	2.8	0.5	0.29
Median mortgage repayment (AU$)	2,106	2,000	520	3500	483
Median Age	37.6	37	59	24	4.74
Total number of observations	102,846				

†Represents the distance to the closest power plan.
‡Neighbourhood characteristics are for each suburbs.

Second, the geo-spatial data were collected to determine the proximities to key amenities such as distance to closest school, shops, parks, coastline, river and water bodies. In addition, the distances to the closest power plant which is the main interest of our study were also extracted. We obtain the proximity measures related to each power plant type. i.e. coal-fired, gas-turbine and gas-reciprocal. These data were extracted using ESRI ArcGIS package. These distances were calculated using Euclidean distance which

Figure 1: The map of distribution of properties



was a measurement of the straight line from the centroid of each property to the closest amenities. Figure 1 and 2 show the location of properties and power plants on the map respectively.

Third, our study area covers whole New South Wales State which includes areas with significantly different socio-economic characteristics. Therefore, we consider demographic characteristics to capture the heterogeneity of the study area. We collected the data on median per capita income, rent mortgage, vehicle ownership on all neighborhoods provided by Australian Bureau of Statics census data. Since 2011 is census year in Aus-

Figure 2: The map of power plants' locations

tralia, we have accurate information on demographic characteristics in each postcode.[5] Table 1 shows the summary statistics of the home and neighborhood characteristics.

The final source of the data is on power plants. We observe the exact location of each power plant with their capacity and the type of fuel they use.[6] Table 2 provides information on each power plant we considered for this study.

[5]The state of New South Wales (NSW) is divided into 604 postal areas. Each area has a four-digit postcode, starting with number 2 for NSW. For instance, the postcode for Sydney CBD is 2000.

[6]It is important to mention that all the coal power plants were operational during the year 2011 and at least ten years earlier. However, Munmorah was decommissioned in 2012, Redbank and Wallerawang were also withdrawn by 2014.

Table 2: List of Coal, Gas and Gas reciprocal Power Plants in NSW

Name	Fuel type	Capacity (MW)	CO2 Intensity‡	Location
Bayswater	Coal	2640	982	Muswellbrook
Eraring	Coal	2880	981	Dora Creek
Liddell	Coal	2000	1008	Muswellbrook
Mount Piper	Coal	1400	1055	Lithgow
Munmorah	Coal	600	1132	Doyalson
Redbank	Coal	150	1290	Warkworth
Vales Point	Coal	1320	1053	Mannering Park
Wallerawang	Coal	1240	1082	Wallerawang
Colongra	Natural gas	667	718	Colongra
Tallawarra	Natural gas	435	476	Wollongwong
Smithfield	Natural gas	176	417	Smithfield
Uranquinty	Natural gas	640	590	Uranquinty
Appin Mine	Gas (reciprocating)	55.6	342	Appin
Tower Mine	Gas (reciprocating)	41.2	321	Appin
Lucas Heights	Gas (reciprocating)	23	941	Lucas Heights

‡ KG CO2 per 1 MWH Electricity
* Power plants with capacities above 20MW were included in this table.

5 Results

The hedonic price model is specified in the logarithmic price of residential properties as a function of their physical characteristics and environmental variables and the socio-economic structure of rural districts where the residential houses are located. As explained in Section 3, all the explanatory variables related to physical characteristics, number of bedrooms, number of bathrooms, number of car parks, pool, fireplace and distance measures are incorporated into the hedonic price models in a linear form and socio-economic characteristics are incorporated as a log form.

Two forms of measures related to the effect of coal and gas are incorporated to the model. The first form includes the intercept dummies to Coal, Gas and Gas (Reciprocating) power plants. The second form is the slope dummy measures. The effect of the power plants on discounting the house prices would fade away with the distance; therefore, a maximum radius of the distance is needed to gauge the effect. In addition, the maximum radius of the likely effect would depend on the type of power plant. Therefore, we conduct our assessment with varying radius measures to filter the correct distances. We conduct this assessment in two steps. First we conduct our estimation with a common filtering on the radius for all types of power plant. Then the assessments were conducted for varying filters for each power plant type.

We estimate three versions of the model with and without spatial errors using property transactions records of 102,846 in year 2011 and the methodology discussed in Section 3. The estimates for spatial models were obtained using the modified versions of the codes provided by Spatial Econometrics Toolbox for Matlab (by J. P. LeSage). Maximum likelihood estimates for OLS, SEM and SDM are presented in Table 3. The estimates of γ and ρ are highly significant (p-values = 0.000). Therefore, there are strong evidences to suggest the presence of spatial correlation within the sample. The R^2 for OLS, SEM and SDM models indicate that the variation in the log of sales prices explained by variation in the explanatory variables is respectively 0.77, 0.84 and 0.79. Therefore, our discussion focuses on the results for SEM and SDM models. The results show that most of structural and neighborhood variables have expected signs and many coefficients are significant at the 5% level.

5.1 Estimates on power plants

As discussed above, the power plant effects are a function of two forms of variables in the model–an intercept dummy and a slope dummy. Though power plant risk is known to affect the property values, we found the difficulty in the assessment for properties in the coastal regions. This is because the location brings with a range of positive values for environmental features such as coastal views, proximity to the beaches. Therefore, following Rambaldi *et al.* (2013) and Bin *et al.* (2008) the properties that locate less than 0.2 km are removed from the estimation (Bin *et al.* (2008) have used 0.2 as the distance).

Also as mentioned above, a range of distance intervals for these two types of dummies are considered for the estimation. The slope and intercept dummy measures are highly co-linear. Therefore, their statistical significance is evaluated by a joint test F-test as individual t-ratios are likely to be low while they are jointly significant. The likelihood ratio test for null hypothesis that slope and intercept dummies in each interval are jointly zero is rejected at 5 percent level for OLS, SEM and SDM models. Table 3 presents the results with the selected set of distance intervals (The result for other imposed distance intervals are available upon request).

The semi elasticity estimates for the two types of dummies provide the effects in percentage form per km distances as (Hill *et al.* (2008) pp 184-186).

$$\%c \; \textit{change per km} = 100 \times \left[(e^{\theta 1} - 1) + (e^{\theta 1} - 1)\right] \tag{5}$$

Our results for all methods show that the effects of power plants on property values

Table 3: Estimation Results

	OLS		SEM		SDM est. Direct effect	
Variables	Coefficient	t-Stats	Coefficient	t-Stats	Coefficient	Asympt. t-Stats
Intercept	-0.980	-13.556	0.819	6.646		
House characteristics						
Property type	0.223	93.449	0.247	100.63	0.241	93.442
Number of bedrooms	0.162	100.30	0.134	96.718	0.141	97.512
Number of bathrooms	0.107	89.931	0.104	104.28	0.103	95.597
Number of car parks	0.065	57.785	0.058	61.235	0.061	63.587
Pool	0.015	4.353	0.027	9.393	0.024	7.799
Fireplace	0.093	25.831	0.056	18.387	0.068	20.142
Socio-economic characteristics						
Log(Income)	0.333	47.306	0.248	22.086	0.230	18.609
Log(Population)	0.034	11.598	0.037	10.373	0.061	12.075
Log(Rent)	0.217	28.309	0.315	24.828	0.333	21.379
Log(No. of dwellings)	0.000	-24.124	0.000	-20.780	0.000	-14.760
Log(Vehicles)	-0.575	-112.54	-0.431	-55.916	-0.436	-53.984
Log(Mortgage)	0.927	74.998	0.728	41.647	0.694	31.528
Log(Age)	0.358	33.562	0.371	17.805	0.447	18.699
Distance measures						
Dist. to coastline	0.000	-18.750	0.000	-7.086	0.000	-4.003
Dist. to waterway	0.003	5.438	0.001	0.577	0.000	-0.455
Dist. to streams	0.000	3.113	0.000	0.501	0.000	0.875
Dist. to train stn.	0.001	11.614	0.001	1.806	0.000	0.078
Dist. to railway	-0.001	-8.818	-0.001	-1.656	0.000	-0.702
Dist. to schools	-0.021	-15.786	-0.007	-3.925	-0.002	-1.013
Dist. to river	-0.001	-16.850	-0.001	-6.676	-0.001	-3.451
Dist. to industry	0.000	-2.106	0.000	-1.612	0.000	-2.139
Dist. to hospitals	-0.001	-13.488	-0.001	-5.815	0.000	-1.239
Dist. to shops	0.000	3.223	0.000	-0.016	-0.001	-3.192
Dist. to park	0.001	4.747	0.000	-0.419	-0.001	-1.483
Dist. to City Hall	0.000	-13.053	0.000	-9.006	0.000	-7.780
Coal-fired plants						
Dummy less than 15 km	-0.236	-15.273	-0.128	-4.752	-0.081	-2.794
Slope dummy less than 15 km	0.008	5.222	0.002	0.548	-0.002	-0.494
Dummy between 15 and 30 km	-0.247	-10.553	-0.280	-6.454	-0.309	-6.435
Slope dummy 15< >30 km	0.007	7.322	0.010	5.147	0.012	5.934
Dummy between 30 and 50 km	0.152	6.856	0.222	5.078	0.268	5.185
Slope dummy 30< >50 km	-0.007	-11.926	-0.008	-6.677	-0.008	-5.767
Gas turbine plants						
Dummy less than 15 km	-0.053	-7.792	-0.081	-6.713	-0.074	-5.785
Slope dummy less than 15 km	0.003	5.465	0.003	2.986	0.003	2.789
Dummy between 15 and 20 km	0.063	2.004	-0.047	-0.931	-0.029	-0.529
Slope dummy 15< >20 km	-0.004	-2.128	0.002	0.731	0.001	0.446
Dummy between 20 and 30 km	0.241	14.479	0.196	7.638	0.184	6.733
Slope dummy 20< >30 km	-0.011	-17.542	-0.009	-9.584	-0.009	-8.510
Gas reciprocal plants						
Dummy less than 1 km	0.006	0.602	-0.005	-0.340	-0.013	-0.865
Slope dummy less than 1 km	0.004	1.426	0.008	2.145	0.008	2.090
Dummy between 1 and 3 km	0.021	1.729	0.031	1.634	0.015	0.770
Slope dummy 1< >3 km	0.003	1.838	-0.001	-0.282	0.000	-0.099
Dummy between 3 and 10 km	0.047	5.308	0.011	0.788	0.000	-0.011
Slope dummy 3< >10 km	-0.003	-5.940	-0.001	-1.005	0.000	-0.315
Spatial parameters			0.758	358.248	0.695	127.661
R^2	0.776		0.842		0.791	
$\bar{R}^2$	0.776		0.842		0.791	
σ^2	0.070		0.050		0.049	
ln L			40958.5		41958.2	
Total number of observations	102,846					

* Quarter dummies were excluded from the table but included in the estimation.

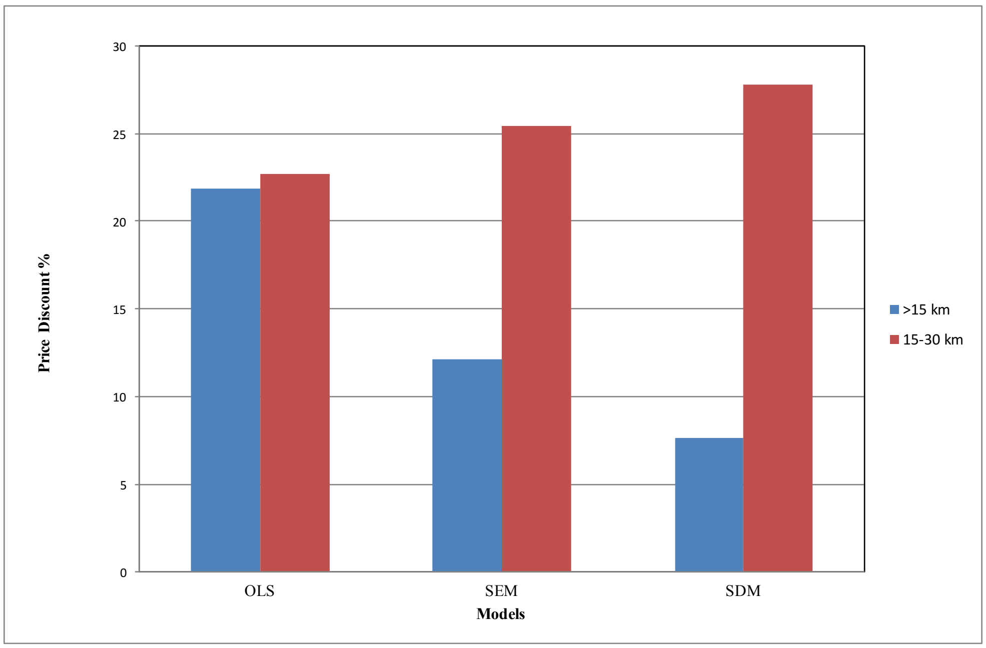
depend on the distance and types of power generation (Table 4). The highest effects are observed for the properties near the coal power plants. In addition, the coal power plants have significant effects on property prices located even within 15-30 km radius whereas the effects of gas turbines are observed only up to 15 -20 km radius. The effects of gas reciprocal power plant last only up to 5 km. However, a caution is needed interpreting these values as the size of gas reciprocal power plants are relatively small compared to the other two types. The maximum capacity of this type is reported by Appin Mine which has around 59.7 MW capacity. But for instance, the capacity of Bayswater power plant, a coal fired type, is 2640 MW.

Table 4: The negative effect of power plants on values

	Discount of price (%)		
Proximity intervals	OLS	SEM	SDM
Coal-fired power plants			
Less than 15 km	-21.85	-12.13	-7.62
Between 15 to 30 km	-22.65	-25.40	-27.81
Between 30 to 50	-	-	-
Gas turbine power plants			
Less than 15 km	-5.53	-8.05	-7.46
Between 15 to 20 km	-	-4.79	-2.99
Between 20 to 30	-	-	-
Gas reciprocal power plants			
Less than 1 km	-	-1.28	-2.08
Between 1 to 3 km	-	-	-
Between 3 to 10	-	-	-

The spatial error model (SEM) and Spatial Durbin model (SDM) show that the properties within 15 km radius of coal power plants experience respectively 12.1 and 7.6 percent of discount in their property values (Figure 3). The respective figures for gas turbines power plants were respectively 8.1 to 7.5 percent (Figure 4). Our estimates show that a property within 5 km radius of gas reciprocal power plant is expected to have a discount of 1.3 percent based on the estimates for SEM and 2.1 percent according to the SDM estimates (Figure 5). The estimates for both models show that the properties within 15-30 km radius of coal power plant experience over 25 percent price discount. The SEM and SDM estimates show around 4.8 to 3.0 percent discounting values for the prices properties within 15-20 km of radius of gas turbine power plants.

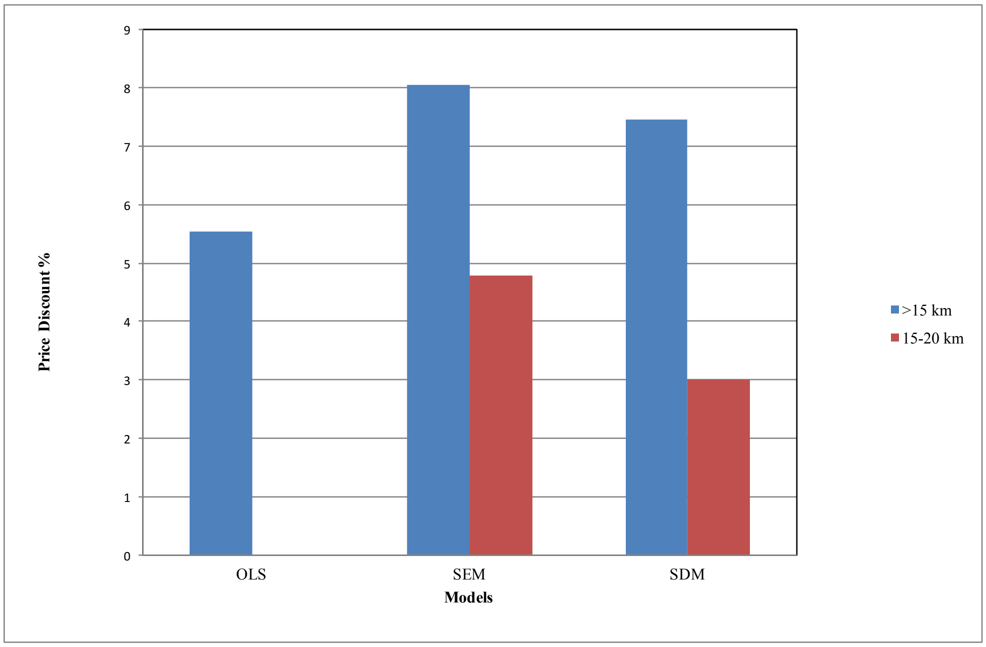
Figure 3



5.2 Estimates on Environmental Amenities

As shown in Table 3, people pay a significant premium for the positive features of the environment. The SEM estimate shows a reduction of 0.05% in property prices per km away from the nearest coast and a reduction of 0.07% for every km away from the nearest river. In addition, the estimate for proximity to railway line shows that the people pay a

Figure 4

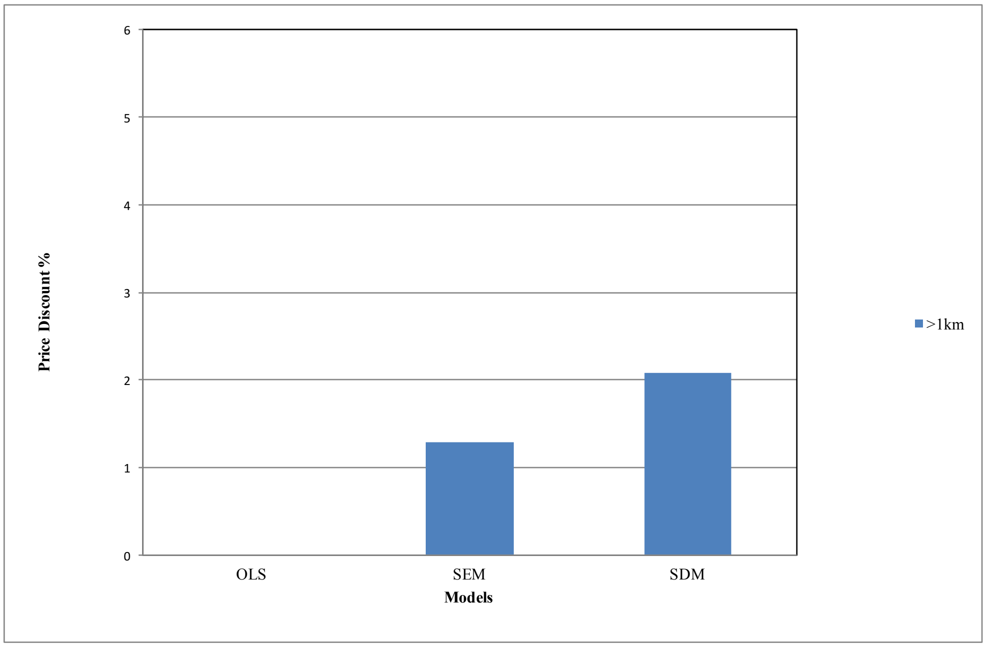


premium of around 0.07% of their price for every km away from the rail line. However, some differences in the estimates in SEM and SDM with respect to distances to environmental amenities can be observed. For example, the estimates for distance to river, is not significant in SDM. Contrary to our expectation, coefficient related to Reserve Park is not significant. This may be due to the fact the reserve park are located in very remote areas where other public facilities are not available at a closer distance compared to other areas.

5.3 Other Hedonic parameters

The estimates for hedonic characteristics (bedrooms, bathrooms, car-parks, pool and fireplace) of the property from both SEM and from SDM (the average direct impact estimates) are significant at 5% level and very similar in magnitude. All these characteristics

Figure 5



have positive effects on house prices. All coefficient related to proximity measures related to shops, hospitals, schools rail stations yield expected signs with 5 percent level of significance. It is important to note here, in the estimation process, we faced a difficulty in isolating the effect of proximity to schools as the prices of properties located in the coastal regions are dominated by the premium paid for the pleasure of the natural environment. Therefore, a filter was introduced to remove the properties that located within 0.5 km radius of the coastline to get the distance measure to schools. The estimates associated with social economic variables from both models are significant at 5% level and very similar in magnitude. All the variables have positive effects except number of vehicle ownership. In addition, all quarterly dummies are significant at 5 percent level.

Our Spatial error model (SEM) indicates that a house is 28% higher in values than a unit. In addition, people in NSW pay around 11 percent additional value for every bed room and 14 percent for a bath room and around 6 percent for a carport. The results show a decrease of 0.68% per km away from school, 0.13% per km away from hospitals and 0.06% per km away from railway station implying that the people value the closeness to these amenities. In addition, our SEM shows a reduction of 0.02% in property prices per km away from the heart of the Sydney city area. Contrary to our expectation, our results indicate that people like to be closer to the industrial areas. They pay around 0.02 percent price per km closer to the industrial areas according to our estimates. This may imply that living closer to industrial areas reduces their traveling time. However, our results report an increase of around 0.001% per km away from shops.

The results on socio-economic characteristics show that they have significant effect on property prices implying that the differences of demographic characteristics play significant role in determining property prices. These variables are included in log form; therefore, the estimated coefficient are elasticities. Our estimates show that one percent increase in median income level in a suburb would result in 0.25% increase in property. As expected the number of dwelling, amount of weekly rent and mortgage pay have positive effects on property prices. Out results show a positive relationship with the age and property values.

We included quarterly dummies to capture any seasonal effects in property prices. All the dummies were significant and show that higher property prices would observed in the second quarter- during April to June which is the end of financial year in Australia.

Our results show that coal power plants have the highest effect on property prices and their effects are observed for longer distances compared to the other two types. The lowest effects are observed for gas reciprocal power plants and its effects are observed only up to 5km radius. The results on distance measures related to the coast and river imply the aesthetic effects due to environment brought positive impacts on property price.

6 Conclusions

This paper investigated the locational effects of a fossil burning power plant on neighborhood property values. We show a significant negative externality impact of a power plant location on property prices with a comprehensive data on regional Australia which gives rise to important policy implications. Since there is no cap and trade market for emissions in Australia and firms do not pay any tax or levy for the amount of emission the produce, our results suggest the negative externality in this market could be more than the direct effect of pollution to the air quality. In fact, with these externalities since firms are not regulated we can simply end up at a non-socially optimal amount of emission in this market. On way of preventing this is to decommission power plants with higher emissions and substitute them with newer technologies. However, in the short term this could not be possible and therefore, a permit market can reduce the amount of the emission produced by firms. Then the regulator can compensate households for the negative effect they received on their properties due to being in a particular distance to a power plant. Of course, the existence of a permit market would also encourage firms to increase their efficiencies and apply new technologies to reduce emission.

An alternative environmental policy option would be to set a carbon price equal to the social cost of emissions that are levied on the polluters in line with the polluters pay principle. Our estimations provide directions towards conceptualizing what an appropriate social cost of carbon will be. A cost reflective price of carbon would also enable Australia in achieving the national renewable energy target of 33000 Gwh since this will level the playing field to compete for both the fossil fuels and renewable energy.

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