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The impact of mining and smelting activities on property prices: a study of Mount Isa city, Queensland, Australia

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Abstract

Much publicity has been given to the problem of high levels of environmental contaminants, most notably high blood lead level concentrations among children in the city of Mount Isa due to mining and smelting activities. The health impacts from mining related pollutants are now well documented. This includes published research being discussed in an editorial of the Medical Journal of Australia (see, for example, Munksgaard, Taylor and Mackay, 2010). On the other hand, other negative impacts of pollution such as the impact on property prices, although mentioned, have not been examined to date. This study rectifies this research gap. This study uses a hedonic property prices approach to examine the impact of mining and smelting related pollution on nearby property prices. The hypothesis is that those properties closer to the lead smelters have lower property (house) prices than those that are farther away. The results of the study show that marginal willingness to pay to be farther from the pollution source is AUS $7,514 per kilometer within the four km radius selected. The study has several policy implications and they are discussed briefly. We used the OLS (Ordinary Least Squares), GWR (Geographically Weighted Regression) and the SAR (Spatial Autoregressive) models for this analysis.

Key words: Property prices, hedonic price model, Mount Isa, mining and smelting related pollution

1. Introduction

Much publicity has been given in recent years to the problem of negative impacts of mining activities on surrounding communities and the environment in Australia. The negative impacts on communities referred to are mainly on health and property prices[1]. Whilst some of the health impacts are quite well documented and discussed (see, for example, Jones, 2009; Munksgaard, et al., 2010) and some health studies are ongoing, the impacts on house prices have been mentioned (see, for example, Cartwright, 2010; Living with Lead Alliance (2010), but not examined in any detail to demonstrate the likely negative externalities on property values (e.g. house prices). This paper addresses this issue using a hedonic property (HP) price study. The city of Mount Isa is selected as a case study, although many other mining and smelting sites with a surrounding population can also be selected for a study of this nature.

The city of Mount Isa is an ideal site to conduct a HP price study to determine the impact of pollution on property (house) prices. First, the health impacts from pollutants from mining and smelting are well known and documented and much publicity has been given to this problem. Hence, the community in the city of Mount Isa is assumed to be aware, at least to some extent, of the health problems arising from pollution. It is also assumed that the community is aware that properties farther from the mining and smelting sites are likely to be more valuable than those that are close to the source of negative externalities. Second, growth of the city of Mount Isa – which dates back to the 1920s – has evolved in such a way that its current population of approximately 23,000 are located both living in close proximity and farther from the source(s) of lead smelting. This enables selecting a relevant sample for a

[1] The property prices in this study refer to only residential properties.

study of this nature. Third, the data for this study are available from many sources, including RPdata, Australian Bureau of Statistics (ABS) and Google Maps.

Interestingly, Mount Isa is a city that has grown and owes its existence, to a large extent, to mining and smelting activities and at the same time most residents are affected from the very activities which a large majority of the community rely on for their livelihood, either directly or indirectly. In this paper it is hypothesised that pollution is an issue that residents and buyers are aware and of its effects on property (house) prices. Hence, it is hypothesised that properties (houses) close to the source(s) of pollution have lower prices than those that are father away. In other words, residents are willing to pay (WTP) more to be farther from the pollution source(s) and to minimise pollution hazards.

The paper is set out as follows. Section 2 provides a brief introduction to the study. Section 3 covers the literature review and Section 4 deals with the data and the estimated models. The regression results are discussed in detail in Section 5. Section 6 concludes with a discussion of the main results and a potential solution to minimise the harmful impacts on the community and property (house) prices.

2. A brief introduction to the study area and its pollutants

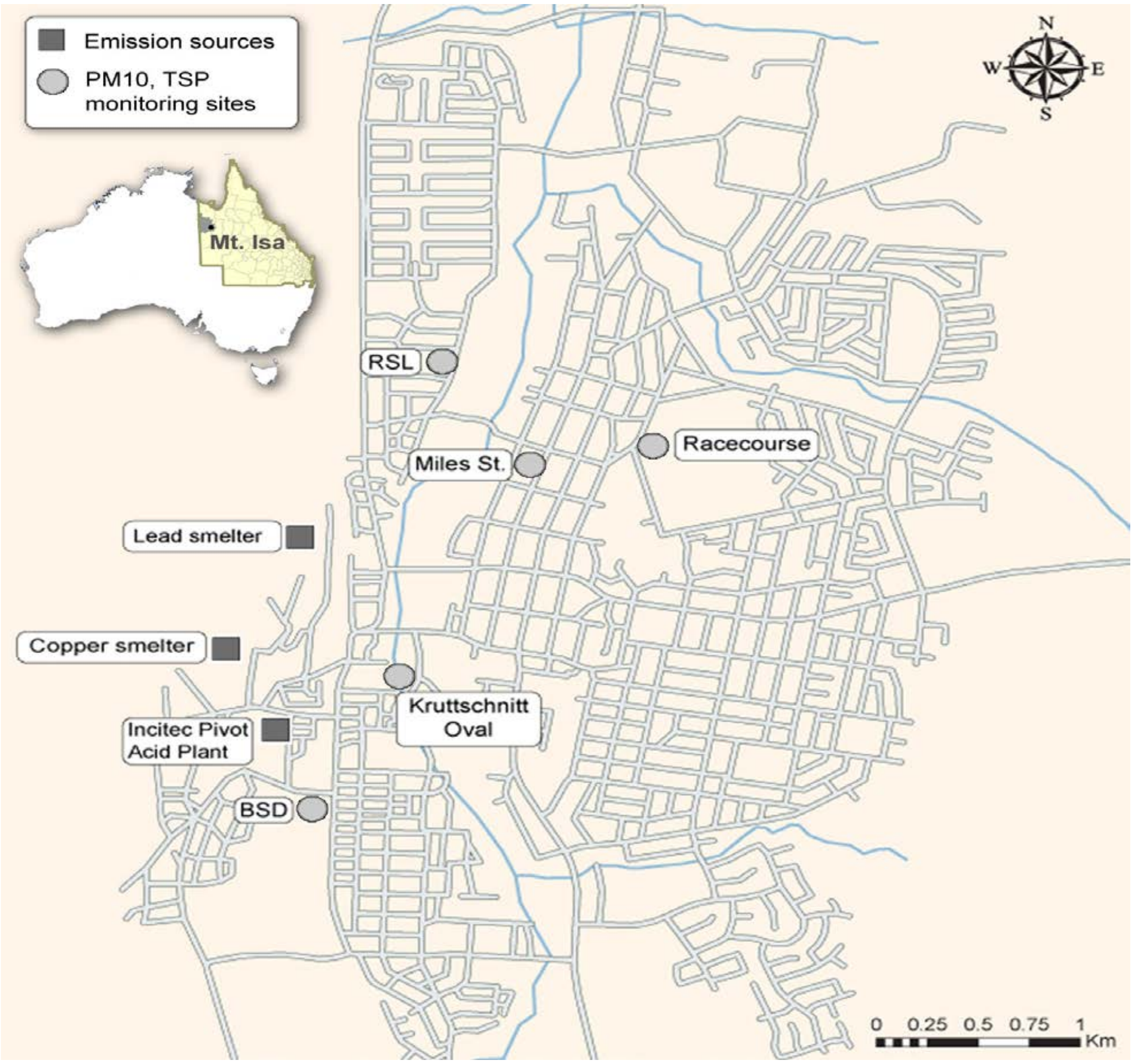
As mentioned above Mount Isa was selected to study the impact of negative externalities arising from lead pollution due to mining and smelting activities. The particular negative externality that has been discussed widely is the impact of lead pollution and airborne pollutants such as total suspended particulate matter on residents' health, especially children in Mount Isa. Studies conducted elsewhere confirm that such pollution impact on human health (see, for example, Gulson, et al., 1998; Jones, 2009; Pope et al., 2002). The impact on residents' health from mining and smelting related pollution (e.g., lead) in Mount Isa is, therefore, assumed to have an impact on nearby property (house) prices as well. It is acknowledged that these 'pollution effects' may have been magnified because of the considerable publicity generated in the local and national media about the incidence of lead poisoning, especially among children close to where the lead smelting takes place (see, for example, Dayton, 2007; Gerard, 2006; Ryan, 2008; Ryder, 2010). The issue of lead poisoning has also been discussed in medical journals such as the Medical Journal of Australia (see, for example, Munksgaard, et al., 2010). As would be expected, information provision about negative externalities is likely to result in a lower appeal for residents to live in close proximity to the source of the externality. This would be reflected in lower property (house) prices.

The district of Mount Isa is located in North Queensland, Australia approximately 900km to the west of Townsville and approximately 1,900km north-west of Brisbane. It borders the Northern Territory (NT) to the west where no residential settlements can be found. The distance to the NT border is approximately 152km. The district itself takes its name from the mining city of Mount Isa. The Mount Isa city which is 43,310 sq.km had a population of 21,082 in the mid 2000s (Australian Bureau of Statistics, 2006) which increases to approximately 31,000 when the surrounding district is included (Australian Bureau of Statistics, 2006; Mount Isa City Council, 2006).

Mount Isa is the administrative, commercial and industrial city for Queensland's north-western region (see Figure 1). The city's main industrial activity is mining which is one of the most productive single mines in the world based on combined production of lead, copper, silver and zinc (see, for example, Taylor and Hudson-Edwards, 2008). Most of the major mining activities date back to the 1920s and full production occurring in the early 1930s (Taylor and Hudson-Edwards, 2008).

Over the past decade the widespread publicity relating to negative environmental externalities in Mount Isa has concentrated on lead pollution. Lead poisoning of residents in Australia is not a new phenomenon and pollution of this nature has occurred in Port Pirie (South Australia) in the early 1980s and in Broken Hill and Boolaroo (New South Wales) in the early 1990s (Gulson, et al., 1998). In Mount Isa, high blood level concentrations have been confirmed since 1994 and have been the subject of much discussion since then (see, for example, Munksgaard, et al., 2010). In addition to the above mentioned areas, in more recent times, lead poisoning fears have arisen in the port of Esperance due to the escape of carbonate during loading of shipments (see, for example, Cartwright, 2010; Heyworth and Mullan, 2009). New lead poisoning fears and its impact on property prices have also surfaced due to the Western Australian Government's decision to permit the shipping of lead through the port of Fremantle (see, for example,Jones, 2011). In this case residents' lead poisoning fears can be sourced to lead spillage while being transported to and being loaded onto ships at Fremantle. The production itself takes place in Wiluna mine, approximately 950km northeast of Perth.

In addition to lead poisoning, other pollutants arising from mining activity in the city of Mount Isa are known to affect its residents (see, for example, Munksgaard, et al., 2010). As mentioned earlier, the city of Mount Isa, apart from being a major producer of lead is also a major producer of copper, zinc, and silver and is Australia's largest atmospheric emitter of sulfur dioxide, lead and other metals (National Pollution Inventory, 2009). As the Medical Journal of Australia (Munksgaard, et al., 2010, p.131) editorial states '*Research* *commissioned during a Queensland government-led inquiry a decade ago, as well as subsequent peer-reviewed studies, have unequivocally demonstrated widespread contamination of soil and airborne dust in an around Mount Isa, as a result of both historic and ongoing mining and smelting activity'*. The contaminants referred to include lead, copper and other metals and metalloids (Munksgaard, et al., 2010).



Source: Adapted from Department of Environment and Resource Management (2009).

However, it is lead poisoning that has captured the most attention, especially in recent years (see, for example, Munksgaard et al., 2010). As the Medical Journal of Australia review concludes '*The evidence is clear. There is a single primary source of environmental lead in Mount Isa: the historic and ongoing mining and smelting activity. Acceptance of this patent fact by all stakeholders will lead to a more targeted remedy to the lead problem, and better health and environmental outcomes for the community of Mount Isa*'.

Based on Munksgaard et al. (2010) Medical Journal of Australia editorial comments it is now clear that environmental contaminants are present in the city of Mount Isa and the most notable is lead poisoning which has an adverse impact on the health of the city's residents. This paper examines the impact of such negative externalities on nearby property (house) prices within an approximately 4 km radius of the lead smelting site (see Figure 1).

3. Literature Review

A large number of studies have been conducted to demonstrate how various factors influence property (house) prices. This literature review provides only a brief review of the relevant literature to the present analysis. Rosen (1974) and Freeman (1979) listed environmental attributes amongst other variables in measuring people's WTP for housing with different attributes. Also in some other studies it is assumed that the negative externalities generated from an environmental disamenity on residential properties can be measured using a distance based approach (see, for example, Nelson, 1982; Palmquist and Smith, 2001; Wisinger, 2006). Most of these externalities affect property (house) prices in a fashion of spatial distribution.

According to the relevant literature, the HP method is an ideal and a powerful tool that could be used to assess property prices in relation to certain characteristics, such as environmental quality (dis-amenities), neighbourhood and structural characteristics. There are several characteristics which effectively determine property prices. These factors include the number of bathrooms, number of bedrooms, size of the house, age of the house, distance to environmental amenities or dis-amenities, distance to the supermarket, distance to the school, distance to the central business district and level of income. A large number of studies have used the HP approach to capture the price of environmental quality/amenity through property (house) sales prices. The extensive use of this approach is indicative of its acceptance in measuring the impact of externalities in environmental valuation studies. A literature search conducted for this study shows that papers examining the impact of lead poisoning on property (house) prices are limited. In fact there is one paper that examines the impact of lead pollution on property (house) prices in Anniston, Alabama, USA due to the presence of an Army depot. A HP price study is undertaken which shows that lead cleanup is likely to increase property prices by US$1,140 per household. The paper also shows that living one km closer to the polluting site reduces property prices by approximately two percent (Affuso, Parisot, Ho and Hite, 2010). Apart from this study it is not easy to find any published literature that examines the impact of lead levels on property (house) prices. However, there are several newspaper articles that mention the likely impact of lead poisoning on property prices (see, for example, The Sydney Morning Herald, 2009). On the other hand HP approach is a famous method in economic literature to quantify the negative environmental effects on house prices.

Ridker and Henning (1967) studied the relationship between sulfate levels and variation in property prices in Illinois and Missouri, USA. According to their findings property price differences disappeared when air pollution was reduced. This can be used as a way of assessing benefits of air pollution alleviating policies. They found that when sulfate levels dropped by 0.25mg./100cm^2/day, the price of that particular property could be expected to rise by at least $83 and more likely closer to $245. These findings are consistent with the findings of Kim, Phipps and Anselin (2003). This study, too, shows that property prices increase when pollution decreases. Simons, Bowen and Sementelli (1999) have examined the effect of leaking underground storage tanks from gas stations in Ohio and showed that these gas leaks reduced the sales price of properties in the vicinity by 28-42 percent.

Smith and Huang (1993) conducted a meta-analysis using nearly thirty seven published studies to verify the linear combination of air pollution on property prices. They used a *probit* model to estimate how data, model specification and local property market conditions in cities influence the ability of HP models to uncover negative, statistically significant relationships between house prices and air pollution measures. They concluded that HP models have been successful in establishing a strong relationship between air quality conditions within a city at different residential sites in relation to house prices. Smith and Huang (1995) used HP price models during the period 1967-1988 to assess the marginal willingness to pay (MWTP) for reductions in air pollution. They showed that market conditions (imperfect information, time on the market and supply and demand booms) and procedures used to implement HP models were important for MWTP estimates.

With respect to lead poisoning in the City of Mount Isa, Taylor and Hudson-Edwards (2008, p.194) state that '*Given that the City of Mount Isa is directly adjacent to Mount Isa Mine and the City's principal drinking water storage area of Lake Moondarra is downstream of these, elevated concentrations of metals in the river system and in soils and sediments around the* *urban area might be problematic'*. Their fieldwork which involved testing soil samples showed that lead and other heavy metal concentrations were above the standard concentrations. They state '*The data demonstrate that the Mount Isa Mine is the primary source of sediment-associated metals*' (p.198). In addition to lead pollution affecting water sources and soils, lead can also be dispersed in the atmosphere in gaseous form (see, for example, Mukai et al., 1993).

Tyrvainen (1996) showed the positive impact of urban forests on nearby property prices using apartment sales data (1,006 apartments) in Joensun, a town of 48,000 inhabitants in North Carelia, Finland. Benson et al. (1998) estimated the price of a 'view' amenity in a single real estate market in Bellingham, Washington. They concluded that the WTP for the visual amenity was quite high.

Shultz and King (2001) showed that proximity to large protected natural areas, golf courses, class II wildlife habitats and percentage of vacant land were positively related to prices. Bowes and Ihlanfeldt (2001) examined the direct and indirect effects of transit stations on the attractiveness of nearby neighbourhoods. This study showed that when the households are situated farther from a highway and a railway station, the property prices increase. The increase in property prices is not significant within the first half to one kilometer contour ring, but is significant for the second and third kilometer contour rings. The marginal property price increase from a highway and a rail transit per unit increase of distance are 7.7% and 3.5% respectively. Dowes and Zabel (2002) used the impact of school characteristics on property prices using data for Chicago during the period, 1987-1991. They assigned to each house a school and they found that school performance (i.e. test scores) had a significant impact on house prices.

In addition, the HP method is widely applied to explore the relationship between various urban types and property prices and the implicit marginal prices of various ‘urban type’ components. For example, street patterns (Guttery, 2002), amenities (Shultz and King, 2001; Benson, Hansen, Shwartz and Smersh, 1998), proximity to transit stations and commercial centers (Bowes and Ihlandfelt 2001; Song and Knaap, 2004) have been some of the factors used in the HP analysis.

Kim et al. (2003) used a spatial econometrics HP model to estimate the response of the marginal price of houses to reductions in SO_2 and NO_X concentrations for the Seoul metropolitan area. This study also looked at variables such as schools and supermarkets in gauging these property prices. All these studies clearly demonstrate that there exists a negative relationship between air pollution and property prices. However, Kim et al. (2003) found that some features of urbanisation were reflected in increased property prices. These features include better connections with street networks, more streets, shorter cul-de-sacs, smaller block sizes, better pedestrian accessibility to commercial uses, more evenly distributed mixed land uses and proximity to light rail stations. Some features that decreased property prices were: higher housing density, areas with increased commercial activity, multi-family and public use facilities (relative to single family use), and access to major transportation arterials. Song and Knaap (2004) incorporated quantitative measures of mixed land uses in the HP analysis. They found that housing prices increased with their proximity to public parks and/or neighbourhood commercial centres.

Nicholls and Crompton (2005) studied the effects of green belts on property prices and salability. They found that while no negative impacts were generated by the existence of green belts, they could be neutral or positive. Wisinger (2006) stated in his PhD thesis that hazardous waste disposal sites has a negative impact on the nearby property prices. This analysis was based on the distance based criteria from the waste disposal site to a particular property. It showed a positive relationship with property prices when distance increased. Mundy (1992), too, had earlier provided supportive evidence to this effect. HP studies conducted by Edd and Sclar (1974) and King (1977) also show the importance of considering the existence of public service utilities in close proximity to a property and the amount of taxes paid by households.

According to the above literature review it becomes clear that a large number of studies have been conducted using HP price studies to demonstrate the impact of environmental aspects on property prices. However, to our knowledge this is the first time there has been an investigation of the impact of mining and smelting related lead pollution on residential house prices. Therefore, this study contributes to an important and highly relevant topic in the HP price literature.

4. Data and the estimated model

For this study we collected a sample of 300 property (house)property transactions data from within a four kilometer distance from the site of the lead smelter (see Figure 1). However, it should be noted here that the copper smelter and the incitec pivot acid plant are also located close to the lead smelter (see Figure 1). Out of the house sales data sample of 300 we were able to use only 284 observations covering 63 streets due to missing values in some of the collected data. The data used in this study covers the period, 2000 to 2010 and were obtained from several secondary data sources. The real estate data (including sale price and house attributes) were obtained from RP Data (2011). The subscription based RP data is widely used by property buyers in Australia and New Zealand and it records all property sales transactions. It should be noted here that only single family real estate transactions were recorded for this study. Any transaction which listed a relationship between a buyer and a seller or any government purchase of a property was disregarded. Also disregarded were properties with land size greater than half an acre (2000 m^2). In this type of market, lot size tends to be skewed toward smaller lots with very few sales of properties greater than one acre recorded. This approach follows Lewis, Bohlen and Wilson (2008), who also point out that by removing larger lots avoids the problem of inadvertent capture of the prices of potentially developable sites.

The spatial data relating to distance was obtained from Google Maps which could be freely accessed (Google, 2011). ABS (2006 census) data are used for socio-economic variables (ABS, 2006). The spatial variables measured using Google Maps were: distance to the lead smelter, nearest state school, nearest supermarket and the nearest community park. These variables represent the locational importance of the property (house) in relation to the distance to amenities and dis-amenities. The distance to the lead smelter site was measured using the direct distance measuring tool in Google Maps (Google Maps Labs). It is important to measure distance accurately since it is a common understanding that air pollution related externalities are known to affect households in a linear manner. The use of a distance variable as a source of revealing negative externalities is common in HP studies (see, for example, Morancho, 2002; McCluskey and Rausser, 2001; Nelson, 1982; Nicholls and Crompton, 2005; Pope, 2007; Wisinger, 2006).

The number of bedrooms (*Bedrooms*) and bathrooms (*Bathrooms*) act as a proxy for dimensions of the house which may vary independently of land size. The number of carport space is deemed important since many households possess one or more automobiles. This variable includes both lock up garages and carports since both provide shelter and an additional level of security to car owners. *Logsize* is simply the size of the property and is measured in square metres. Distance to supermarkets, schools and parks represent access to community and commercial areas. While the proximity to supermarket and school is considered as a convenience measure, the proximity to park represents a recreational/aesthetic amenity. In order to assess the effects of mining and smelting related pollution on residential house prices, the distance from the lead smelting site to properties (houses) within a four kilometre distance (*Distance*) was included in the study. This is an important variable in this study. This is because it is hypothesised that those properties that are closer to the lead smelter have lower property (house) prices than those that are farther away. The dummy variables for year of sale (D_2004, D_2005, D_2006, D_2007, D_2008, D_2009, and D_2010) are designed to capture any time trend in the housing market during this period. Any sales occurring between 2000 and 2003 are excluded for identification purposes. The definition of the variables and their expected sign are shown in Table 1.

Table 1: The definitions of independent variables used in the HP prices study and their expected signs.

Variable	Description	Expected Sign
Bedrooms	Number of bedrooms	+
Bathrooms	Number of bathrooms	+
Carport	Number of carports	+
Logschool	Log distance to the nearest state school(km)	-
Logsupermar	Log distance to the nearest Coles supermarket(km)	-
Park	Distance to the nearest recreational park(km)	-
Distance	Distance to the mining and smelting sites	+
Logsize	Log size of the land (sq.metres)	+
Mhiwk	Median household income (Aus$/week)	+
D_2004	Dummy; 1 if year of sale is 2004 and 0 otherwise	+/-
D_2005	Dummy; 1 if year of sale is 2005 and 0 otherwise	+
D_2006	Dummy; 1 if year of sale is 2006 and 0 otherwise	+
D_2007	Dummy; 1 if year of sale is 2007 and 0 otherwise	+
D_2008	Dummy; 1 if year of sale is 2008 and 0 otherwise	+
D_2009	Dummy; 1 if year of sale is 2009 and 0 otherwise	+
D_2010	Dummy; 1 if year of sale is 2010 and 0 otherwise	+

Note: Data between 2000 and 2003 are used as the base year data to compare whether the property prices in other years are different. We used the period, 2000-2003 as the base since there are only a few observations for a given year during this period in our sample.

Several econometric issues and problems arise in the estimation of the hedonic models (see, for example, Cassel and Mendelsohn, 1985; Huh and Kwak, 1997). For example, the theory provides little assistance in specifying the functional form of the hedonic equation, which, however, is known to influence implicit prices. The different functional forms such as linear, log-linear and log-log have been used in previous studies. However, there is no evidence to show that one functional form is better than the rest. Cassel and Mendelsohn (1985) suggested that the estimates of the environmental variable coefficient may be more reliable with simple functional forms. Palmquist (1991) argues that as the environmental variable plays a secondary role in determining housing prices, complex mathematical transformation might result in less accurate parameter estimates. We tested the results of different functional forms in the present study. The following normal equation was found to provide better results. Accordingly, the model that is used to analyse the determinants of property prices is given by Equation (1):

$$\begin{aligned} Ln\_Price = {} & \beta_0 + \beta_1\, Bedrooms + \beta_2\, Bathrooms + \beta_3\, Carport + \beta_4 Logschool \\ & + \beta_5 Logsupermar + \beta_6 Park + \beta_7\, Distance + \beta_8\, Logsize + \beta_9 Mhiwk \\ & + \beta_{10} D\_2004 + \beta_{11}\, D\_2005 + \beta_{12}\, D\_2006 + \beta_{13}\, D\_2007 + \beta_{14}\, D\_2008 \\ & + \beta_{15}\, D\_2009 + \beta_{16}\, D\_2010 \\ & + \varepsilon \qquad (1) \end{aligned}$$

Initially, an ordinary least square (OLS) model was estimated and tested for the presence of heteroskedasticity and the spatial model used for the interpretation was estimated with robust standard errors. As shown by Anselin (1988) spatial-autocorrelation/spatial dependence is one of the main consequences of using geographic data, especially when the properties are located close to each other. Spatial dependence occurs when the price of a property located in a particular suburb is determined both by its own characteristics and the characteristics of nearby properties as well. Spatial autocorrelation is observed due to the omitted variables which include characteristics of neighbouring locations. Hence the error term is spatially correlated. Interestingly, until recently, not many papers have tested for spatial autocorrelation (German, Hand, Fontenla and Barrens, 2010). Some of the recent studies that have accounted for spatial autocorrelation include Anselin and Lozano-Garcia (2008) and German et al. (2010).

Moran's I statistic is used to provide proof of spatial dependence which takes into account the level of spatial clustering or dispersion patterns. Moran's I statistic ranges between -1 to +1 where -1 implies extreme negative spatial autocorrelation (aggregation of dissimilar prices) and +1 implies extreme positive spatial autocorrelation (clustering of similar prices). The Moran's I is calculated using the property price and for this study Moran's I statistic shows the presence of spatial dependence (see, Table 3). Moran's I is estimated using the following equation:

$$Moran's\ I = \frac{n \sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij} (y_{i} - \bar{y})(y_{j} - \bar{y})}{(\sum_{i=1}^{n} (y_i - \bar{y})^2 \left(\sum \sum_{i \neq j} w_{ij}\right)} \qquad (2)$$

In Equation [2], y_i is the property price and $\bar{y}$ is its mean value. W is the spatial weight matrix that is used in the SAR model in Equation [3].

We follow the spatial expression below in estimating the spatial lag model (SAR). Equation [3] gives the matrix representation of the general model. In this, Z is the dependent variable (i.e., $Price$) and X is a vector of independent variables. β's are coefficients to be estimated and ρ is the spatial dependence parameter.

$$Z_L = \rho W Z_{L-1} + X\beta + u \qquad (3)$$

In Equation [3] Z_L is the price of the property in location L and Z_{L-1} is the lag price of theadjacent locations. W has the properties of row standardised, symmetric and is an inverse distance weight matrix.

Failing to include this lag price variable as an independent predictor has a significant impact on the model specification, when spatial dependence is present (Moran's I is significant). The next section shows the results for the estimated models using OLS, GWR and the SAR.

5. Results and discussion

Table 1 presents the descriptive statistics of all variables in our empirical analysis. Variables such as distance to school, distance to supermarket and the size of the land have been transformed into natural logs. Table 2 shows the descriptive statistics of the selected variables.

Table 2: The descriptive statistics of the selected variables

Variable	***Mean***	***Std.Div***	***Min***	***Max***
price	250,467	104,045.7	48,000	580,000
bedrooms	3.17	0.70	1.00	6.00
carport	0.86	0.90	0.00	6.00
bathrooms	1.13	0.40	1.00	4.00
distance	1.94	0.76	0.09	3.50
school	1.80	0.84	0.10	4.30
supermarket	1.59	0.66	0.04	3.10
park	0.40	0.19	0.06	1.50
size	827.25	167.87	504.00	1556.00
mhiwk	1544.00	242.95	611.80	1921.80
d_2004	0.10	0.31	0.00	1.00
d_2005	0.16	0.37	0.00	1.00
d_2006	0.13	0.33	0.00	1.00
d_2007	0.18	0.38	0.00	1.00
d_2008	0.10	0.30	0.00	1.00
d_2009	0.13	0.34	0.00	1.00
d_2010	0.11	0.32	0.00	1.00

Note: More details about the definition of each variable are given in Table 1. ***Std.Div*** stands for standard deviation of the variables

Table 3 shows the regression results for OLS (Ordinary Least Squares), GWR (Geographically Weighted Regression) and the SAR (Spatial Lag Model) analyses. As can be seen the results of three models are similar for most of the variables and all the variables have the same signs. The interpretation of the results should be based according to the functional form used for the study. The OLS results show that the model explains about 83 per cent of variations in the property prices while the GWR also shows similar results. However, OLS and GWR do not account for spatial dependence which is shown in Moran's I statistic which is 0.03 (see, Table 3). Hence we use the SAR model for the interpretation of the coefficients. Most of the variables are significant at one per cent level. However, of the neighbourhood characteristics, the median household income (suburb average) is not significant in all the three models. One possible reason for this could be the limited variation of data available for median household income.

Table 3: The regression results of OLS, GWR and SAR functions

Variables	***OLS***		***GWR***		***SAR***	
	Coefficient	***t-Value***	***Coefficient***	***t-Value***	***Coefficient***	***t-Value***
bedrooms	0.033***	3.84	0.034***	3.84	0.032***	3.79
carport	0.013**	2.14	0.014**	2.14	0.014**	2.41
bathrooms	0.071***	4.72	0.071***	4.72	0.071***	5.01
distance	0.031***	3.53	0.031***	3.53	0.027***	3.34
logschool	0.030	0.83	0.030	0.83	0.029	0.84
logsupermar	-0.005	-0.23	-0.005	-0.23	-0.003	-0.18
park	-0.054*	-1.77	-0.054*	-1.77	-0.053*	-1.82
logsize	0.295***	4.13	0.295***	4.13	0.272***	3.96
mhiwk	0.000	0.59	0.000	0.59	0.000	0.42
d_2004	0.017	0.69	0.017	0.69	0.014	0.59
d_2005	0.173***	7.66	0.173***	7.66	0.171***	7.93
d_2006	0.307***	12.91	0.307***	12.91	0.305***	13.41
d_2007	0.465***	20.84	0.465***	20.84	0.460***	21.5
d_2008	0.501***	20.09	0.501***	20.09	0.496***	20.81
d_2009	0.465***	19.64	0.465***	19.64	0.457***	20.04
d_2010	0.476***	19.68	0.476***	19.68	0.474***	20.51
R^2	0.8311		0.8311		N/A	
Ajd. R^2	0.8209		0.8209		N/A	
Moran's I	0.03**	2.22				
Rho					0.11***	2.68
WaldTest(rho=0)Chi^2					7.18*** (0.00)	
LR Test (rho=0)Chi^2					7.04***(0.00)	

Note: ***, ** and * denote significant variables under 1, 5 and 10 per cent levels of significance respectively.

As mentioned earlier, we use dummy variables for the ‘year of sale’ to capture the temporal variation of property prices. Our focus in this study is on the *Distance* variable which describes the effects of mining and smelting related pollution on the property prices. A priori expectation for the *Distance* variable is that it should correspond positively with the property prices in such a way that when the residential properties are located away from the pollution source, the prices tend to increase with the distance. This is because the dispersion of the pollutants in the air and soil tends to reduce with the increased distance. The marginal WTP for being away from the source of pollution-point is Aus$ 7,514 for one kilometre increase of the distance from the mining site. This phenomenon is similar to a number of studies which examine the relationship between environmental pollution and appreciation of the property prices as the distance from the source increases (see, for example, Nelson, 1982; Wissinger, 2006). According to Nelson (1982) this price discount is most prevalent within a four kilometre radius from the source of the pollution. However, it should be mentioned here that it depends on the type of pollution.

The structural characteristics have the expected signs since they tend to increase property prices. As expected, structural characteristics such as number of bedrooms, bathrooms and carports have significant impacts on property prices. The coefficients for *Bedrooms* and*Bathrooms* are significant at one percent level of significance and the *Carport* variable is significant at the five percent level. The variable *Logsize* is significant and is positive as the a priori expectation. Distance to supermarket and the recreational park have the expected signs as hypothesised. However, the distance to supermarket is statistically insignificant. The distance to school does not have the expected sign but is also statistically insignificant. The purpose of using sales year dummy variables as mentioned earlier was to capture the temporal fluctuations of property prices. The results show that property prices have increased during the mid 2000s and however since 2008 it has declined but has stabilised in 2010. This is most likely related to prevailing market conditions in the property market during this time rather than due to any pollution related information becoming available to buyers. In order to demonstrate that the overall decline in property prices within the study area in the later part of 2000s was due to more information becoming available to buyers about lead poisoning is difficult to prove without undertaking a field survey of residents in the area. However, the regression analysis (distance variable) clearly shows that properties (houses) that are located closer to the lead smelter have lower values than those that are located farther away.

6. Conclusions

As discussed, HP price studies show that the price of a property (house) is related to a number of factors such as the characteristics of the property, attributes of the neighbourhood and environmental characteristics. These attributes influence property prices. They can either have a positive or a negative effect on house prices or account for a premium depending on the price buyers place on them. The expectation is that different attributes or characteristics will produce differences in property values and that pollution (e.g. lead) resulting from mining and smelting is also likely to have a negative impact on property prices. This was revealed in the literature review undertaken for this paper. As discussed, this study used a HP price study to determine whether such a relationship also exists in the case of Mount Isa where many studies have shown that the level of pollution – and especially that of lead - is high particularly in areas close to where the mining and smelting activities occur. In addition, the health effects of pollution, especially lead, have been reported in the local and national media (see, for example, Cartwright, 2010; "Mount Isa Children: lead exposure and your child," 2011; "Queensland Government: Environment and Resource Management," 2011; Ryder, 2010). Hence, the community of the city of Mount Isa has become aware of the problems arising from pollution. We, therefore, hypothesised that properties closer to the source of pollution are likely to have lower property prices than those that are farther away. The OLS, GWR and SAR models show that this is the case and is significant at the one percent level.

The study and literature review show that all structural variables and neighbourhood variables, except school have the correct signs. However, the distance to school variable is statistically insignificant. Most variables are significant at one percent level. The results are consistent with other HP studies conducted relating to environmental externalities (see, for example, Weicher et al. 1982; Sirpal, 1994; Cheshire and Sheppard, 1998; Des Rosiers et al. 1996; Hui et al. 2007; Jim and Chen, 2009; Sirmans et al. 2005; Tyrvainen, 1997).

There are a number of important policy implications stemming from the regression results which clearly show that property prices close to the source of pollution are lower than those farther away.

It is, therefore, clear that remedial action is required given this study shows that there are dual health and lower/depreciation of housing price problems arising from the proximity of houses to mines and smelting activities. These are persuasive reasons for relocating residential and public utilities away from the mining-related activities. In terms of land availability such an exercise would appear to be feasible given the size of the district and its small population. The key issue of course would be related to the cost of re-location.. However, given the incomes generated from mining activities and the longevity of these mines, the costs should be within the means of the stakeholders involved. The political will to act by relevant authorities should be based on a careful cost benefit analysis based not only health issues, but also, as this study shows, on the impact mining-related activities have on property prices as well.

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Table 7: Correlation matrix of the variable used in the hedonic property valuation study

	bedrooms	carport	bathrooms	distance	logschool	logsupermar	park	logsize	mhiwk	d_2004	d_2005	d_2006	d_2007	d_2008	d_2009
bedrooms	1														
carport	0.1964	1													
bathrooms	0.3291	0.0397	1												
distance	0.0162	0.1246	-0.0374	1											
logschool	0.1998	0.1382	-0.2056	0.4927	1										
logsupermar	0.0224	0.0666	-0.1802	0.1312	0.4168	1									
park	0.0532	-0.0567	0.1338	-0.0839	-0.1287	-0.1024	1								
logsize	0.0431	-0.0076	0.1231	-0.3775	-0.3058	-0.0906	0.3435	1							
mhiwk	0.1505	0.1217	-0.1412	0.393	0.6937	0.3984	-0.133	-0.2524	1						
d_2004	0.1362	0.0266	0.1244	-0.0146	0.026	0.0272	-0.012	0.1095	-0.0496	1					
d_2005	-0.065	-0.0923	-0.0219	-0.0248	-0.0448	-0.026	0.0689	-0.0347	-0.0671	-0.1507	1				
d_2006	0.0791	-0.0617	-0.0402	-0.0028	0.0016	0.0001	-0.053	-0.04	-0.0048	-0.1285	-0.1676	1			
d_2007	-0.097	-0.0123	-0.0771	0.0246	-0.0436	-0.0186	-0.089	0.0245	-0.022	-0.1566	-0.2042	-0.1741	1		
d_2008	-0.114	0.0252	-0.0177	-0.0344	-0.0159	0.0009	0.0563	-0.0013	0.005	-0.1133	-0.1478	-0.126	-0.1535	1	
d_2009	0.042	0.1193	0.085	0.0101	-0.0331	0.0196	0.078	-0.0351	0.0325	-0.1326	-0.173	-0.1475	-0.1797	-0.1301	1

Note: Correlation matrix is produced using Stata 11 software. It shows the magnitude of the relationship among variables