Aggregate Resource Extraction: Examining Environmental Impacts on Optimal Extraction and Reclamation Strategies

by

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Abstract

Aggregate resources are naturally occurring deposits of sand, gravel and crushed stone that are integral components to the construction of everything from roads and sidewalks, to hospitals and schools. Mining these resources can release deleterious sediments, salt and chemicals into watercourses, soil and the air and can affect scenery. The structure of these environmental externalities raises questions about the optimal extraction of aggregate resources, the timing of reclamation activities, and the appropriate distance gravel mines should be from their market. A social planner optimizing aggregate extraction and incorporation of the effects of the externality may choose a different extraction path and reclamation strategy than a private operator. Hedonic price analysis and difference-in-difference modelling are used in this research to measure the effect of the negative externalities from an aggregate mine in Calgary, Alberta on nearby property values, and to examine how reclamation can address those effects. The empirical hedonic price model findings are used to develop a simulation of gravel mining operations with the incorporation of private and social costs to examine the benefits of locating mines in remote locations versus in close proximity to their intended market, and strategies for reclamation timing.

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Table of Contents

List of Tables

List of Figures

1. Introduction

1.1 An Overview

Aggregate resources are naturally occurring deposits of sand, gravel and crushed stone often referred to simply as “gravel”. These deposits are the result of the erosion of bedrock whose particles were then transported most commonly by water or glacial ice, making them most abundant in areas near historical or present rivers (Langer et al 2004). Gravel is a non-renewable resource that is a component of everything from roads, sidewalks, homes, hospitals and schools to numerous manufactured goods including glass and pharmaceuticals. Almost all structures and roads are constructed using aggregate in some form, making it impossible to construct or expand cities without it.

Gravel has a low unit value and is expensive to transport because of its weight. As a result, it is generally extracted in closed proximity to its intended market or end-use. Transporting these materials long distances can result in costs higher than the value of the resource itself, and thus operations are commonly located near developing urban centres (Richards and Peel 2003). Furthermore, gravel operators argue that being closer to their intended market decreases their environmental footprint by decreasing the distance large trucks need to travel with the resource (B&A Planning Group 2012). Although there are numerous issues associated with gravel mining such as impacts on the landscape, water quality and quantity and loss of agricultural land, trucking of aggregate resources is often the most visible and is responsible for generating several environmental externalities which most concern the public such as dust, noise, traffic and degrading road conditions. Believing it will reduce the impact of trucking, the Ontario Government and the Calgary Aggregate Producers have adopted a “close-to-market” strategy. This strategy prioritizes gravel operations that are closer to their market versus those that are further.

A challenge for policy makers and operators is accessing the necessary aggregate resource for construction, while maintaining environmental integrity and minimizing the disturbance to nearby residences. Often as community development expands closer to the source of aggregate, the negative externalities of the mine become increasingly apparent as they negatively impact property values. The first set of analysis in this research has the intent of identifying the magnitude of the impact of these externalities from a specific gravel mine on property values in nearby neighbourhoods. This will be done using hedonic price analysis accompanied by difference-in-difference (DD) modelling during the life cycle of the gravel mine.

In the second section of the analysis, the empirical hedonic price model findings are used in conjunction with various costs associated with gravel transportation to create a simulation model for a hypothetical mine. The simulation model is intended to evaluate the externality effects of the gravel mine and compare these with transportation costs to identify whether it remains efficient to mine in close proximity to the market when social costs are considered.

Without taking into account the social costs of extraction, the high cost associated with freight transport of gravel appears too high to locate mines too far from their market. Furthermore, industry considers the environmental footprint generated by gravel extraction significantly reduced if the distance gravel must be transported is shortened by extracting near the resources' intended end use or market. The simulation model will estimate the magnitude of social costs associated with extraction and compare this additional value with freight transport costs. When considering both direct and social costs of extraction against the transportation cost, the common perception that shortening the distance the resource must travel to reach its intended market reduces the operation's environmental footprint and costs may be challenged.

The simulation model is also an attempt to create a dialogue on optimal reclamation timing. If the negative externality of a mine extends through time until a reclamation certificate is issued, then reclaiming sooner would reduce the duration of the negative externality on the value of surrounding households. Currently Alberta is regulated by guidelines that do not provide strict reclamation timing schedules to mine operators. By demonstrating the elimination of the social costs associated with aggregate extraction once reclamation has been completed, this research hopes to provide evidence of the economic benefits of timely reclamation.

1.2 Aggregate resource mining in Alberta

Alberta has four sources of aggregate: preglacial deposits of sand and gravel, bedrock, glaciofluvial deposits and recent alluvial deposits (Peel 2004). Approximately 90% of aggregate resources in Alberta are a result of the last glaciers in the province, with the remainder from recent alluvial deposition (RAMP). These are predominately Early Tertiary to Recent sedimentary deposits (Richards and Peel 2003). These aggregate resources have been used in Alberta since the turn of the twentieth century when there was an enormous influx of European settlers, causing the need for the construction of a railway and road networks (Peel 2004). As the population grew so did our needs for aggregate resources. Edwards (1998) estimated that use jumped to approximately 2.2 billion tonnes from 1950-2000, and will continue to grow to about 5.0 billion tonnes between 2000-2050. There are approximately 5962 aggregate pits in Alberta of varying sizes (Walls 2001), a majority of which are owned privately (Alberta Environment and Sustainable Resource Development). B&A Planning Group (2012) estimated that in Calgary alone annual consumption per capita of aggregate is approximately 10 tonnes and annual demand overall is estimated to be 11.3 million tonnes per year. There is an estimated stock of 200 million tonnes of aggregate available within both approved private and municipal aggregate operations (B&A Planning Group 2012). This will satisfy short term needs for the next approximately 20 years.

In Alberta, the sand and gravel resources are most commonly used for road and building construction, cement making, applying sand to roadways in the winter, for filtration in septic tanks, and as protection against erosion for shorelines (Government of Alberta 2009). Approximately 64% of all aggregate resources in the province are used for construction, and 19% for concrete production. Alberta also produces bricks and other ceramic products from clay and shale, as well as "Alberta rainbow rocks" which are used in landscaping (Government of Alberta 2009). Approximately 99% of demand for aggregate in Alberta is met by sand and gravel deposits mined almost always within a 42 km radius of urban centers (Richards and Peel 2003).

In Alberta, as a result of the *Sand and Gravel Act* (1951), surface materials are most commonly the property of the landowner. Furthermore, the *Law of Property Act* (1980) assigns the rights to gravel deposits to the titled land-owner. This results in equal competition between government, commercial operators and municipalities interested in receiving rights to extract gravel on private land (CharettePellPoscente Environmental Corp. 2013). Only when gravel deposits are on public land do Alberta Environment and Sustainable Resource Development (ESRD) have the jurisdiction to allocate licenses and enforce environmental standards. The federal government also requires approvals under the *Fisheries Act* as administered by the Department of Fisheries and Oceans (DFO) for any development which may cause alteration, disruption or destruction of fish habitat. As a result, only environmental and safety issues pose constraints on development on private lands, with operations smaller than five hectares (Class II Pits) not requiring environmental approval to begin production. Furthermore, private ownership has resulted in Alberta's lack of adequate information on the production rates and reserve estimates for private operations, as well as incomplete records of public land operations as they are not required to report production and reserve estimates (Richards and Peel 2003).

1.3 Environmental Impacts of Aggregate Resource Mining

Aggregate resource extraction is known to potentially release deleterious sediments, salt and chemicals into watercourses, groundwater sources, soil and air often from erosion. Of particular concern are the noise, dust, water contamination, soil contamination, traffic, negative impacts on road conditions, and negative visual aesthetics associated with their development.

There are approximately 5960 pits in Alberta, resulting in 260 km^2 of surface disturbance (Peels 2004). According to R.D. Peel (2004), if the estimation is correct of 5.0 billion tonnes of gravel consumed from 2000-2050, this will result in approximately 940 km^2 of surface disturbance. This disturbed landscape may result in the introduction of invasive plant species and noxious weeds, which have negative consequences for nearby vegetated areas including riparian areas.

Air pollution as a result of aggregate resource mining is composed of two main types. The silica-rich dust generated during extraction, otherwise known as Total Suspended Particles (TSPs), is the result of crushing, driving on haul roads, stockpiling and screening (B&A Planning Group 2012). The heavy machinery used to mine and freight-transport the resource generally burn diesel fuel which generates Particulate Matter (PM). Aggregate operations in Alberta are required to meet certain strict air-quality standards for PM developed by Alberta Environment because it has been linked to health issues associated with lungs and the cardiovascular system.

Gravel operations typically generate varying levels of noise posing concern to nearby residents (B&A Planning Group 2012). Extraction, crushing and screening and trucking are the most noticeable sources of noise pollution. Because gravel mines are typically situated so proximally to their market, it is a challenge for operators to attempt to mitigate this noise.

In terms of water pollution, it is the long term effects of contamination of aquifers and poisoning of surface water bodies that present the largest issues (Richards and Peel 2003). 20% of drinking water used by North Americans is taken from aquifers (Pielou 1998), while Albertans relied on groundwater for 27% of their freshwater needs (Environment Canada 1999). In Alberta most of the sand and gravel deposits are sealed from surface contamination by a layer of impermeable clay-rich glacial tills (Richards and Peel 2003), which once removed for mining allows the permeable materials below to easily conduct contaminants such as fuel oil spills, runoff containing fertilizers, pesticides, herbicides and sewage directly into an aquifer below (Richards and Peel 2003).

The objective of this research is to evaluate the impacts of the negative externalities generated from a gravel mine on nearby property values. Assessing the impact of these issues is challenging as a result of there being no explicit market value assigned to externalities such as air and water pollution. To carry out the analyses, a hedonic property value analysis, difference-in-difference (DD) analyses and a simulation model were used to attempt to quantify this impact. The site chosen to carry out these analyses is Carburn Park in Calgary, Alberta. Carburn Park was originally an operating gravel mine from 1982-1985, and was announced as a park in 1986. The park features walking trails, picnic areas, and ponds stocked with fish for anglers. It officially received a reclamation certificate about 20 years later in 2005. This is an excellent place to carry out such an analysis because gravel is a required resource for developing municipalities, and Calgary has been rapidly expanding for many years. Furthermore, data were available covering time periods before extraction took place until after reclamation occurred. It should be noted however, that the number of available operations prior to extraction are significantly fewer than those available after.

1.4 Overview of Results

The results from this analysis provide evidence of a significant negative impact on property values as a result of the environmental externalities generated by the gravel mine. During mine operation there is a downward pressure on property values in the surrounding neighbourhoods. After reclamation occurs however, this impact is reversed and property values increase as their proximity to what became Carburn Park increases. The difference-in-difference DD model further supports this finding, with results that also show the positive impact of reclamation. The inclusion of the social costs into the simulation model suggest that in the case of this mine, it may have been more cost effective to move the mine anywhere from 40 to 60 km away from its market if such resources exist at this distance. This finding counters the common perception that transporting gravel large distances is both more expensive and generates a smaller environmental impact.

1.5 Contribution to the Literature

There is limited work published in the literature that directly measures the economic impacts of environmental externalities from gravel mining. Although there are numerous papers which perform hedonic price analyses of housing impacted by various other industrial activities, there are few published papers relating to gravel mines. Of these examples, I could not find an analysis from Canada. This research will contribute to the literature relating to gravel mining in Canada by including hedonic property value and DD estimates of the impacts on property values generated by gravel mining. The research also examines the changes to social costs associated with the location of gravel mines in areas relatively closer to and further from development. Finally, the simulation helps to inform our understanding of the value of more rapid reclamation when sites are located in developing areas.

2.0 Hedonic Property Value Analysis

2.1 Literature Review

Hedonic property value models are indirect valuation methods using observable data for obtaining and understanding values of varying attributes of products which are heterogeneous in nature (Boxall et al 2005). This definition suggests that housing markets are excellent subjects to use for hedonic price analyses. To evaluate the impacts of the gravel pit on nearby neighborhood prices, it is important to examine the literature on property value analysis in general as well as studies of the impact of mine sites on property values.

Rosen (1974) outlined basic hedonic price functions in his seminal paper which has since been used in many analyses, beginning with his initial analysis using housing markets which he expressed in the following way:

(1) $P_i = \beta(X_{i1}, \dots , X_{iJ}; \varepsilon_i)$

Where

P_i = the observed price of commodity *i*;

X_{i1} = amount of some "characteristic" j per unit of commodity

ε_i = a disturbance term.

Each household is a heterogeneous product, composed of a series of attributes that differentiate it from the other households in the market. In response to this supply of heterogeneous products, the market in turn provides the equilibrium prices for those products as they correspond to quality. The hedonic price function characterizes this equilibrium price, connecting the amount offered by buyers to the amount accepted by sellers. In other words, the hedonic price function can be considered an envelope of bid functions for all participants in the housing market (Muehlenbachs et al 2013). Considering this point, the obvious correlation of the bid function and the indifference curve becomes apparent.

In his paper, Rosen (1974) described the potential role of environmental attributes alongside a bundle of housing characteristics in determining housing values. As a result of the observable nature of locational choices and neighbourhood amenities, it is possible to tease out preferences for environmental attributes alongside those of the household itself. Put another way, this means we can estimate an individual's willingness-to-pay for an attribute (for example distance from a gravel mine) by examining the change in price of the household as a result of variations in that attribute (Muehlenbachs et al 2013). In the case of environmental disamenities, such as air pollution generated at a gravel mine, what is often being estimated are individuals' willingness-to-pay to avoid that attribute.

There are numerous examples of studies examining the property value impacts of such environmental disamenities. The locally undesirable attribute ranges in these studies from sour gas wells in Canada (Boxall et al 2005), shale gas development in the United States (Muehlenbachs et al 2013, Gopalakrishnan and Klaiber 2013), the Sydney Tar Ponds on the East coast of Canada (Neupane and Gustavson 2008), to hazardous waste sites in the United States (Ihlanfeldt and Taylor 2004, Messer et al 2006). Each of these studies finds noticeable effects substantial enough to support the notion that these wide array of environmental hazards each produce negative downward pressure on nearby household values.

Boxall et al's (2005) paper is developed around a spatial lag model to capture the spatial dependence between neighboring properties and estimate the impact of oil and gas wells on nearby property values. The analysis was executed using data composed of housing sale prices from 1994 to 2001 which included more than six townships. The most appropriate functional form, where hedonic price analyses often differ, was determined using Box-Cox regression procedures to be a log-log formulation. The results indicate a negative impact on property values as a result of nearby sour gas wells.

Muehlenbachs et al (2013) use a triple difference estimate to assess the impact of shale gas development and resulting perceived groundwater risk to property values in Pennsylvania. They find that there are economic gains to be had as a result of development which result in higher property values with increase proximity to shale gas wells. However, this positive impact is entirely reversed when households attain their water through groundwater sources rather than being piped in from a municipal source indicating individuals' aversion to groundwater risk.

In their analysis of shale gas exploration in Pennsylvania, Gopalakrishnan and Klaiber (2013) found similar results. One of the first empirical analyses of the impact of exploration activities, they found heterogeneous impacts on households depending on their location relative to major roadways, water sources, proximity to agricultural land and the intensity of activity. The impacts in their study were found to be inconsistent over time.

The Sydney Tar Ponds have a reputation as once being one of the most contaminated sites in Canada. The result of a one hundred year major steel industry on the East Coast of Canada, the tar ponds posed served as a lingering reminder of the significant soil and water contamination dividing the various communities of the town of Sydney, Nova Scotia. Though the negative impacts of the contamination were often downplayed by the government, numerous studies implied significant health impacts associated with the contaminants floating in the tar ponds. Neupane and Gustavson (2008) performed an analysis of the impact of these perceived health risks and concerns over public image of the community as these contaminants became well known on a national scale, and how these impacted property values within Sydney. Their results indicate a loss in property value as a result of these contaminated to sites to amount to approximately $36 million. Their analysis also examined the value of site remediation relative to the welfare gains it can provide to society, indicating they believe it should be carried out if the costs of cleanup do not too heavily outweigh social benefits.

Ihlanfeldt and Taylor (2004) performed hedonic price analyses on regions surrounding the United States Hazardous Waste Sites (HWS). Separate price gradients for before and after HWS announcements by the government and a geographical area covering most of the City of Atlanta were used. Housing sale prices from between 1981 and 1998 were included and combined with three environmental databases which indicated the HWS within the region. A model specification which described the price-distance relationship with a reciprocal transformation was chosen. They believed it to be the best as it "implies that price will increase with distance from the HWS at a decreasing rate until at some point, price will not be increase with distance" (pp. 7). To determine model specification, property prices were regressed against property and also industry factors and some variables were excluded because of multicollinearity, another common issue with hedonic price analyses. Finally, the issue of treatment of spatial dependencies was addressed by their incorporation into a spatial lag model. A significant decrease in housing values post-announcement was found in areas where previously there had been little to no negative effects.

Directly related to gravel mining, the work published by Hite (2006) examining the property value impacts of gravel mining concluded that because property value losses increase for households located closer to a mine, new mines should be developed at greater distances to minimize these losses to individuals. Within a 0.5 mile radius from a mine, she estimated a 36% decrease in property values and a 25% decrease for those within 1.5 miles. Her study from Delaware has been cited by numerous consulting companies when preparing reports for other counties in the United States for proposed gravel mines. One such report was prepared by George E. Erickcek (2009) which stated that "a residential property located a half mile from the gravel mine would experience an estimated 20 percent reduction in value; one mile from the mine, a 14.5 percent reduction; 2 miles from the mine, an 8.9 percent reduction; and 3 miles from the mine, a 4.9 percent reduction" (pp. 5). A report done which estimated the impacts of the Rockfort Quarry (W.E. Upjohn Institute 2009) found these impacts to be permanent, not reversing once mining ceased. This relates to the study of stigmatization effects done by Messer et al in 2006 who found that property values can remain significantly depressed even at remediation occurs in significantly contaminated sites.

In some situations "residents or potential buyers are fearful of a site [and] they may respond by shunning neighboring communities…" (Messer et al 2006, pp. 305). In Messer et al's study, they investigate this phenomenon in three communities with nearby Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) sites; also known as Superfund sites. Of particular interest to the authors is how prevalent this stigma effect becomes as site cleanup is delayed increasing amounts of time, up to twenty years. To perform their study, Messer et al. use sale prices for a thirty year period (34 000 sales), across three superfund sites. Their results show that an increase in the number of events, whether positive or negative, have a positive effect on the number of homeowners and potential buyers who stigmatize the communities near superfund sites.

Although using a hedonic price analysis can be a powerful tool for determining the effects of environmental externalities on property values, they are not without their limitations. These problems include but are not limited to; the arbitrary nature of functional form selection, endogeneity due to omitted variable bias, and the treatment of spatial considerations in the error structure of the model (Palmquist and Israngkura 1999, Bockstael and McConnell 2007, Muehlenbachs et al 2013, Boxall et al 2005).

All hedonic analyses are faced with the challenge of functional form and model specification selection, and are considered one of the most arbitrary components to hedonic price analyses (Boxall et al 2005 and Palmquist and Israngkura 1999). Omitted variable bias was the next area of major concern for this research. One source of omitted variable bias occurs when pollution sources are correlated with environmental disamenities, such as gravel mines in neighbourhoods. This unobserved negative external effect, correlated with the observed effect, can generate an upward bias in the coefficient on the observed effect. (Bockstael and McConnell 2007). Furthermore, although data sets on housing value sales are readily available because of the frequency of real estate sales, the socioeconomic data generally required to recover preferences are not. Without this information researchers can only estimate one point of a given household's bid function but not the shape, which because of its direct relation to the indifference curve is what captures information about household preferences. As a result first stage hedonic analyses are usually the extent of analysis that can be performed, as with Boxall et al (2005), which are limited to estimation of marginal willingness-to-pay.

Fixed effects are a method suggested in the literature to attempt to overcome the shortfalls associated with hedonic price analyses such as omitted variable bias. For example, there may be systematic differences in houses closer to a gravel mine than those further away, thus property fixed effects can be employed to difference away these effects (Muehlenbachs et al 2013). These types of spatial fixed effects are recommended by Kuminoff et al (2010) as a means to achieve large gains in accuracy in the evaluation of environmental externalities using hedonic analyses, and to avoid omitted variable bias. Property fixed effects were originally considered as well to account for any systematic differences between those properties in closer proximity to the gravel mine than those further away. If those properties located near to the gravel mine are associated with less desirable effects, then not including property fixed effects would lower the baseline that those households further away are compared to (Muehlenbachs et al 2013). However, because distances to the gravel mine are constant over time, the property fixed effects would be collinear in the model. Thus they are not used in this analysis.

Also suggested in this work is the use of time fixed effects to gain more accuracy of results. Often the impact being examined can vary within time for reasons that are not captured in the explanatory variables in the model, another example of omitted variable bias. By using time dummies for all of the years included in the analysis temporal, effects not accounted for by the explanatory variables can be controlled for.

Difference-in-difference (DD) modelling is suggested by the literature as another method to overcome some of the shortfalls of hedonic price analyses, including sources of unobservable heterogeneity which vary with time (Muehlenbachs et al 2013). The work of Ashenfelter and Card (1985) laid the ground work for what is now a widespread method. In basic DD models, the observed results revolve around two groups and two periods of time. The first group (treatment group) is exposed to a treatment in the second time period only, and the other group (control group) is not exposed in either period. To remove biases in the second time period between the two groups, the average gains from the control group is subtracted by those of the treatment group. In other words, DD models take into account different subpopulations, some of whom are affected by the policy or treatment while others are not, and measure the outcomes from both before and after the policy intervention (Athey and Imbens 2006). This basic model can be specified as follows (Imbens and Wooldridge 2007):

(2) $y = \beta_0 + \beta_1 dB + \gamma_0 d2 + \gamma_1 d2 * dB + \epsilon$

Where

$y =$ outcome being analyzed

$d2 =$ dummy variable for the second time period

$dB =$ difference between treatment and control groups before policy change

$\gamma_0 =$ coefficient for second time period

$\gamma_1 =$ difference-in-difference coefficient of interest representing the interaction term

These models have become particularly popular for the estimation of the effects of various implemented policy changes, and are effective as they address omitted variable bias as well. One of the main assumptions in DD analysis is that without treatment, both the treatment and control groups would be subject to the same average change. As a result, time trends which are unrelated to the policy change can be removed by subtracting the outcome experienced by the control group from the outcome of the treatment group. Therefore, DD removes biases from comparisons of both groups in the latter period that could arise as a result of time-varying unobservable heterogeneity between the two groups. Bertrand et al (2003) argue however, that as a result of serial correlation which has been largely ignored by researchers using this method to this point, DD estimations suffer from severely understated standard errors and over-estimation of significance levels. To identify the treatment and control groups to be used in the DD analysis, Linden and Rockoff (2008) utilize a simple regression to compare property values with distance from sex offender's homes residence for two years before and after to find the distance from which this property decline becomes negligible. At this distance is where the boundary between their treatment and control groups is identified. This method is also employed by Muehlenbachs et al. (2013) in their analysis of the impact of shale gas development on property values.

In addition to these considerations, hedonic property value models lack the ability to include the role of people's preferences in their decision-making process. For example, an individual's preferences may affect what areas they choose to live in. Equilibrium sorting models can be used to understand how consumers will "sort" across neighbourhoods based on factors such as their education, income, and availability of public transportation (Kuminoff et al 2010). As these heterogeneous individuals make decisions about where to live, they effectively alter the demographics in a neighbourhood and the supply of amenities such as pollution and road conditions as a result. For example, individuals may influence policy change that requires more diligence on the part of a gravel operator in terms of road maintenance, thus determining the supply of this amenity endogenously. More intuitively, "the sorting literature seeks to understand 'general equilibrium' feedback effects between economic agents and their environments. For example, a shock to the housing market that induces a change in residential location patterns may lead to a redistribution of local amenities that induces more migration and housing development which continues until prices adjust and markets clear" (Kuminoff et al 2010, pp. 2-3).In the case of this research, certain households may sort themselves based on a non-market feedback effect such as pollution generated by extraction at a gravel mine. This may cause households with certain characteristics and preferences to choose to live closer to or further away from the mine site despite what stage of operation it is in, thus affecting the hedonic price locus. Being privy to this information could provide useful insights and dramatically affect the results of this study. Due to data limitations and the complexity of the method however, it was not employed in this research.

Another important issue for consideration is whether to incorporate spatial error and dependencies within the model. Previous research, such as work by Bell and Bockstael (2000), has demonstrated the importance of incorporating these effects. Spatial autocorrelation can be represented as follows:

$$y = X\beta + \varepsilon \tag{3}$$

where

$$\varepsilon = \rho W\varepsilon + u \tag{4}$$

In this scenario, y is a vector of observations on the dependent variable, X is a matrix of explanatory variables, β is a vector of corresponding and unknown parameters, W is a spatial weight matrix defining the spatial relationships between y, ρ is a scalar parameter to be estimated, ε is a vector of random errors with mean zero and nonspherical variance-covariance matrix, and $\varepsilon \sim N(0,\Omega)$ (Bell and Bockstael 2000 and Boxall et al 2005). If the coefficient ρ has a non-zero value, this indicates the presence of spatial errors. As a result Ordinary Least Squares (OLS) estimates will not be biased but inefficient, and standard error estimates will be biased. Of particular concern is the accuracy of selection of the spatial weighting matrix, which requires choosing the associated properties within a certain distance of the property under consideration, and determining their relative weight against that same property.

These papers provide important insights with regard to how to begin creating an assessment of the impact of gravel pits in Calgary on nearby property values. The most relevant methods employed in these studies are used in this research to conduct the analysis of property values surrounding what was once an operating gravel mine and has since been transformed into Carburn Park. The methods are summarized in the following section.

2.2 Data and Methods

The data used in this study were obtained from The Calgary Real-Estate Board consisting of 6941 home sale prices from 1981-2010. All housing sale prices were converted using the housing price index for Calgary, Alberta from Statistics Canada to allow for equal weighting of the impacts over time. This analysis includes a combination of structural characteristics considered standard in a hedonic price analysis of housing markets, such as the number of bedrooms, number of bathrooms and the age of the house. This data set is not without its limitations, however. According to the Calgary Real-Estate board, there is no way to conclude that all characteristics of households sold were accurately recorded, thus limiting the accuracy of the hedonic analysis. Furthermore, socioeconomic data were not available to perform a second stage hedonic analysis. Table 1 provides a list and description of all included variables.

Table 1 Property Attributes

Variable	Description	Mean	St. Dev.
Log of Deflated Price	Ln of actual sales price of house deflated by the Housing Price Index	12.6244	0.28281
Presence of Air Conditioning	Dummy for presence of air conditioning in house	0.02982	0.17011
Waterfront	Dummy if house is considered waterfront	0.00144	0.03793
Presence of Garage	Dummy if house has a garage	0.526	0.49936
Size of Garage	Area in square Metres	0.90333	0.92157
Lot Size	Area in square Metres	441.137	6132.28
SFhouse	Dummy for whether house is single family house	0.91644	0.27675
Deck or Balcony	Dummy if house has a deck/balcony	0.48149	0.49969
Area of Home	Size of lot in square meters	109.831	32.6728
No. Bedrooms	Total number of bedrooms	0.00929	0.77539
No. Bathrooms	Total number of bathrooms	0.06573	0.6394
Fire Place	Number of finished fireplaces	0.43812	0.56687
Age of House	Age of house	20.84	16.1709
Reciprocal Distance	Inverse distance of house to point in Carburn Park	0.81672	0.70843

As aforementioned, distance from each property in the data set to a center point in Carburn Park was calculated. The area that these sales were selected from can be viewed in Figure 1, where the locations of sales are represented by the circular points. Carburn Park is located immediately west of the Bow River and is indicated in light green. The inverse of this distance was then interacted with dummy variables for property sales before 1985, and after 1985. For this research a first stage hedonic analysis was used in Model 1. The sale price was regressed against all of the structural characteristics listed in Table 1, as well as the two inverse distance dummy variables for the periods before and after mine closure (IDA and IDB).

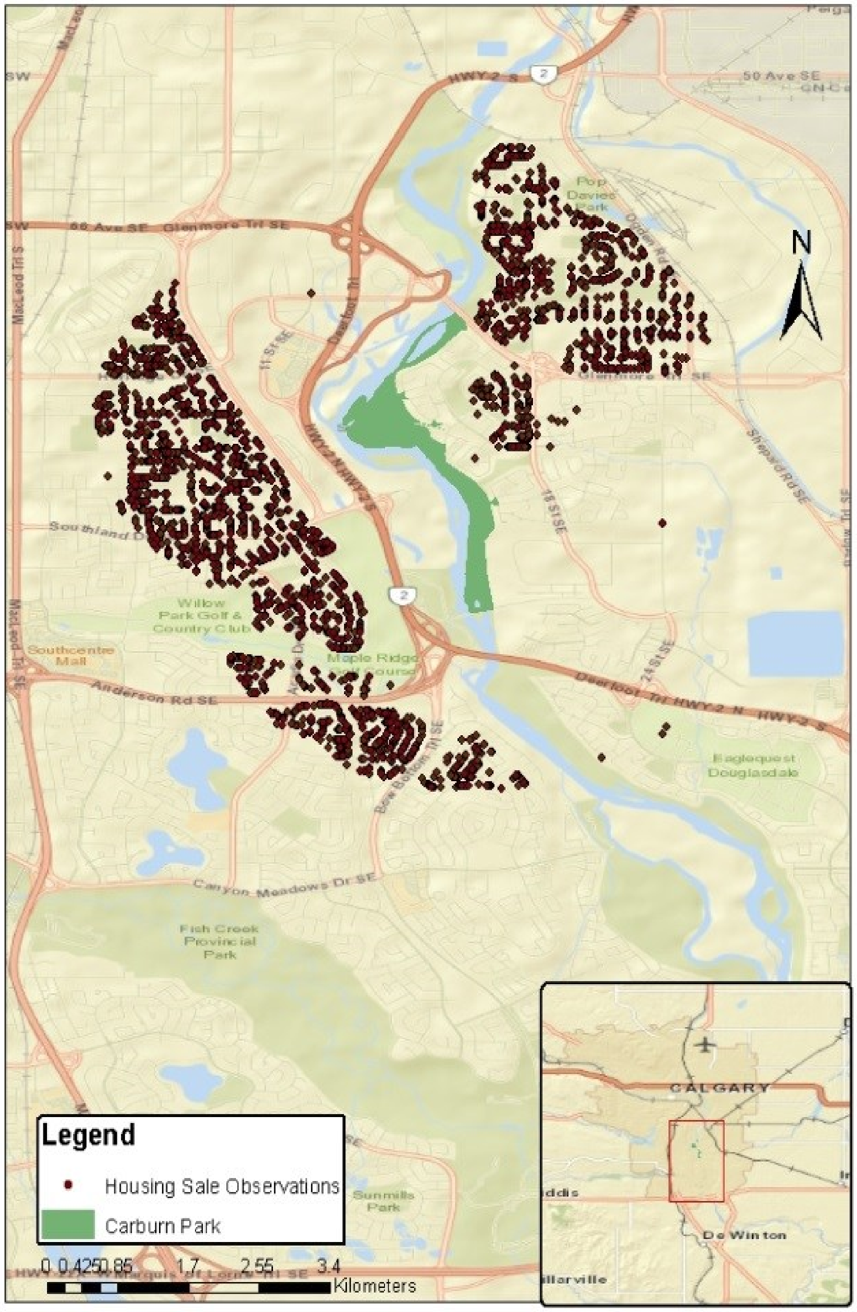

Figure 1 Map of Carburn Park and existing houses in 1985

2.21 Hedonic Price Analysis

The model in this analysis is based upon Ihlanfeldt and Taylor (2004) and their efforts to quantify the effects of property value before and after an increase in public awareness about a contaminated site using a combination of housing characteristics as well as two variables that interact inverse distance with a time dummy indicating the time period before or after mine closure. It is modified to investigate the effects of decommissioning a gravel mine and converting it into Carburn Park in Calgary, Alberta. This gravel mine, which began operations in 1982, finished operation in 1985 and was announced as a park open to the public in 1986 by then Mayor Ralph Klein. A semi-log functional form was decided upon based on the higher goodness of fit when compared to linear or double log functional forms as used in other analyses (Messer et al 2006, Boxall et al 2005). Multicollinearity did not appear to be a problem when choosing model specification as there were only the aforementioned two variables dealing with distance to site. The intent at this stage of research is to investigate whether mine operation had a negative impact on property values, and whether mine closure and reclamation had a positive effect.

The basic hedonic price model to investigate these effects can be expressed in the following way:

$$P_{it} = \alpha + \sum_{j=1}^{J} b_j \, X_{jit} + c_1 ID_i^B + c_2 ID_i^A + \varepsilon_{it} \tag{5}$$

where

P_{it}= log of transaction price of property *i* at time *t, t*=1981-2010,

X_{jit}= *j* property characteristics of property *i* in time *t,* including location-oriented variables,

ID_i^B = inverse distance from property to the park, if sale occurred before the mine closure,

ID_i^A= inverse distance from property to the park, if sale occurred after the mine closure,

ε_{it} = random error.

Eq. (5) assumes that the price-distance relationship is explained by a reciprocal transformation. With this in mind, if the estimated coefficient for distance variable is negative, it indicates that price will increase with distance at a rate that is decreasing until it approaches an asymptotically constant level (Ihlanfeldt et al. 2004). Likewise, if the same coefficient is positive, it implies increasingly positive effects with closer proximity to the park. By separating the sale categories into before and after the announcement the gravel mines closure, it allows the price-distance relationship to vary accordingly. This model will be hereafter referred to simply as Model 1.

2.22 Difference-in-Difference

DD models have commonly been used to identify the effect of various treatments or events. Furthermore, DD modelling is widely considered an excellent method to avoid common econometric problems such as omitted variable bias (Parmeter and Pope 2009). In the context of this research, the DD model can be used to isolate the effect of a nearby gravel pit on property values and, for example, whether or not the mine is continuing to operate. Basic DD models will examine two groups; a control group which is not exposed to a treatment in either period, and the treatment group which is exposed in the second period but not the first. This relationship can be expressed as follows in the context of evaluating gravel mine impacts on housing prices. Two time periods are examined, where the first time period is prior to closure in 1985 and the second period is after. The analysis also consists of two groups, one of which is the treatment group affected by the gravel mine and within a specific distance of the site. The control group is not affected by the gravel mine and is located further away than the houses within the treatment group. The time period for the analysis was selected based upon the time period during which the gravel mine ceased operations, before and after 1985. After a basic examination of the data, there is evidence of a decrease in property values during mine operation that is reversed in 1985 once the mine closes which supports this decision (see Figure 2. The DD analysis will be referred to as Model 2 hereafter[1].

[1] A third model, Model 3, refers to another DD model which interacts the previous DD parameter with the inverse distance to the site. Essentially this model combines the methods of the previous two models to demonstrate how the variation in price as a result of the environmental externalities changes with distance from the site. The results of this analysis are quantitatively similar to the results of Model 1 and Model 2, and are presented in the appendix.

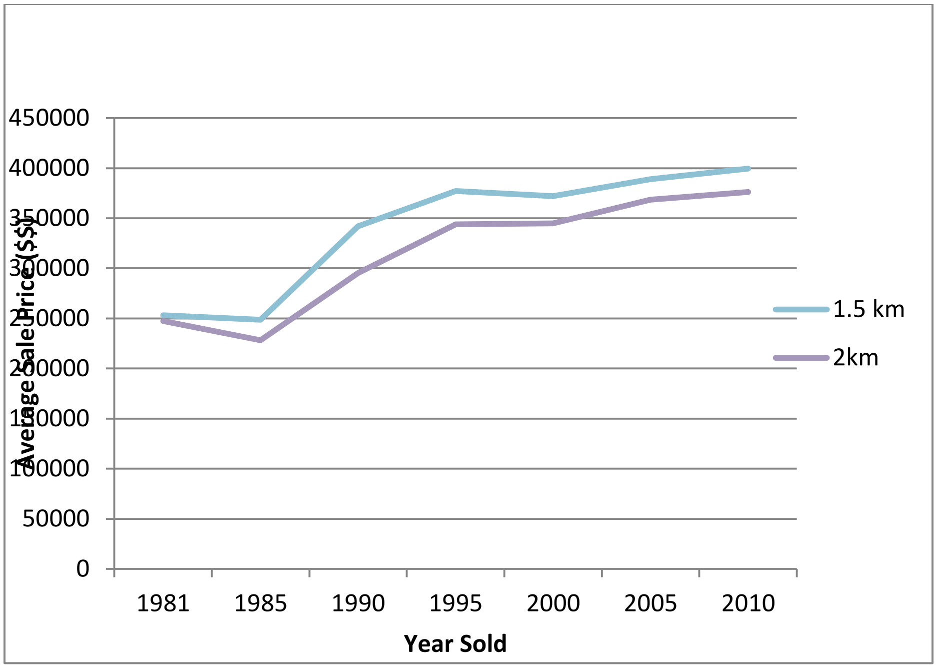

Figure 2 Average sale price from 1981-2010 within 2km treatment zone from Carburn Park

Choosing the correct distance from the site to serve as control and treatment groups was done by comparing the various distances employed in the literature with the size of the area being examined around Carburn Park. The data were analyzed to see how close to the site housing sales were occurring, and until what point there appeared to be a negative impact. A 2 km treatment area was selected as it appeared most appropriate for this site, and also matched well with the treatment areas used in similar research by other contributions in the literature (Linden and Rockoff 2008, Muehlenbachs et al 2013, Boxall et al 2005).

The econometric model for the DD estimation is expressed as follows:

$$(6)\ P_{it} = \alpha + \beta_t X_{it}^T + \beta_R X_{it}^R + \beta_{DD} X_{it}^T * X_{it}^R + \sum_{j=1}^{J} b_j\ X_{jit} + \varepsilon_{it}$$

Where

P_{it}= log of transaction price of property *i* at time *t, t*=1981-2010,

X_{it}^T= a dummy for the second time period

X_{it}^{R}= a dummy for the treatment group within an identified radius

$X_{it}^{T} * X_{it}^{R}$= an interaction term for observations both in period 2 and the treatment group

Table 2 Difference-in-difference parameter description

	Before Mine Closure (B)	After Mine Closure (A)	Difference (A-B)
Treatment (C)	$\alpha + \beta_R$	$\alpha + \beta_t + \beta_R + \beta_{DD}$	$\beta_t + \beta_{DD}$
Control (D)	α	$\alpha + \beta_t$	β_t
Difference (C-D)	β_R	$\beta_R + \beta_{DD}$	β_{DD}

In this type of analysis, the difference-in-difference in parameter (β_{DD}) is the parameter of interest because it is the estimator of the policy effect. Ashenfelter and Card (1985) defined this parameter as;

(7) $$\beta_{DD} = (P_{treatment.,after} - P_{treatment.,before}) - (P_{control,after} - P_{control,before})$$

Table 3 Distribution of observations for DD estimation in Carburn Park

Classification	Observations	Classification	Observations
Before 1985	430 (6%)	Control & Before 1985	211(3%)
After 1985	6511 (94%)	Treatment & Before 1985	219 (3%)
Total	6941 (100%)	Control & After 1985	1989 (27%)
Treatment (within 2 KM)	4741 (68%)	Treatment & After 1985	4522 (65%)
Control (Outside 2 KM)	2200 (32%)	Total	6941 (100%)
Total	6941 (100%)		

2.23 Robustness Checks

A series of robustness checks are used to identify any potential misspecifications in the model. The inclusion of time fixed effects is an attempt to account for time-invariant unobservable effects in each of the analyses performed. To do this, year dummies from every year accounted for in the data set are included in the regression analyses. The analysis was done considering two "before and after" scenarios. The first focussed on the time period before and after mine closure, and the latter on when the reclamation certificate was issued in 2005. Though both scenarios were analyzed, only the first is included in this research. The park had already been functionally usable for residents in the community for approximately twenty years before the reclamation certificate was issued, and as a result the analysis provided positive results for the time periods before and after it was issued. In the case of mine closure and subsequent reclamation however, there were noticeable differences in the property value impacts from either the operating mine or the transformed park. It was decided that this time period better reflected the overall impact on the community from mine closure and reclamation. Breusch-Pagan and White tests for heteroskedasticity were performed, and found the presence of heteroskedasticity.

This was attempted to be corrected for by using robust standard errors in all of the following reported results.

The data are composed of communities located by a major highway, the Deerfoot Trail. To account for any impacts of dust or noise from this highway and to ensure that those impacts are not being combined with the impact of the gravel mine, an inverse distance parameter from each house to the nearest point on the highway was included in the analysis. The highway was not found to have had any impact on the analysis, and as a result is not reported in the results section below.

To formally investigate the issue of spatial autocorrelation, a non-spatial classic OLS regression with the inclusion of various spatial weights was run in GeoDa. This regression provides the results of a Moran's I test for spatial autocorrelation. The test result indicated that the null hypothesis of no spatial autocorrelation should be rejected. The results of the Lagrange Multiplier (LM) test then indicated that there is a presence of dependence among the error terms. Similar to the work of Neupane and Gustavson (2008) however, because there was a low level of statistical significance, and since spatial dependency does not create unbiasedness in the OLS results, the model was estimated without spatial effects[2]. Furthermore, because using DD modelling cancels out any spatial impacts, as discussed in Muehlenbachs et al (2012) and Gopalakrishnan and Klaiber (2013), additional spatial analysis was not conducted.

2.3 Results

2.31 Model 1 Results

The results of the analysis using Model 1, found in Table 4, show a decisive difference in the effect of the gravel mine before and after it closed in 1985. The sign on the coefficient for the variable representing the time period before closure is negative and significant. This result indicates that in that period, property values decreased with proximity to the site. The reverse effect is true in the time period following the closure of the mine, with property values increasing with proximity to what became Carburn Park. This result indicates a negative externality was generated by the operating gravel mine that put downward pressure on property values

[2] These tests were re run using various distance based spatial weights matrices, testing distances from 0.1 km – 0. 5 km, and all provided similar results.

surrounding it. The effect of reclamation moreover, has a significantly positive effect on property values once completed. The signs and magnitudes on the other variables are plausible and as expected, for example an additional bathroom results in an approximate 7% increase to property value while the presence of a garage increases value by approximately 6%.

To test the robustness of these results, time fixed effects were included in the model as aforementioned. Although the signs and significances on most of the variables do not vary much from the original model, the variable indicating the before time period becomes positive and insignificant, indicating some sensitivity around this result. The positive impact from reclamation is still supported by the positive and significant coefficient value on the variable indicating the 'after' time period. Upon a closer examination of the data, it is clear that there are few house sales within the area directly next to the gravel mine, which may account for some of the variability with the results. Furthermore, there is only one year of available data prior to the mine opening, compared with the twenty-five after. Finally, the preferences of the individuals moving into this area before and during production are unknown. It is possible that those choosing to move into this neighbourhood were aware not only of the operating gravel mine, but also of the imminent plans to reclaim it into a user-friendly park. For that reason, that the negative externalities may not have resulted a large impact. What is most important to note however, is the robustness of the result for the time period following reclamation. It is consistently positive, significant, and of noticeable magnitude.

Table 4 Hedonic analysis results using the basic Model 1 structure, indicating impacts of the gravel mine before and after the mine closed interacted with inverse distance from the site

	Model 1	
Attribute	OLS[1]	TFE[2]
Inverse Distance Before	-0.12229***	0.07840
	(0.0248)	(0.0518)
Inverse Distance After	0.056067***	0.04169***
	(0.0071)	(0.0055)
Presence of Air	0.05682***	0.03331***
Conditioning	(0.0098)	(0.0095)
Waterfront	0.07034	0.11573***
	(0.0553)	(0.0344)
Presence of Basement	0.09632	0.04181
	(0.0.0584)	(0.0342)
Presence of Garage	0.01758	0.05609***
	(0.0129)	(0.0108)
Size of Garage	0.06593	0.03733***
	(0.0082)	(0.0066)
Single Family House	0.15521***	0.18907***
	(0.0081)	(0.0064)
Deck or Balcony	0.05331***	0.02408**
	(0.0049)	(0.0040)
Area of Home	0.00232***	0.00189***
	(0.0003)	(0.0003)
Lot Size (m²)	'0.0007	-0.0001
	(0.0005)	(0.0001)
No. Bedrooms	0.01037***	0.00761***
	(0.0031)	(0.0026)

No. Bathrooms	0.08944***	0.06716***
	(0.0053)	(0.0043)
Fire Place	0.05969***	0.05909***
	(0.0059)	(0.0049)
Age of House	-0.00105***	-0.00331***
	(0.0003)	(0.0002)
Constant	11.89602***	11.89159***
	(0.0358)	(0.0508)
R^2	0.66	0.76
N	6941	6941

P<0.01=***, P<0.05=**, P<0.1=*

[1]OLS = Ordinary Least Squares

[2]TFE= Time Fixed Effects

A visualization of the impact estimated in Model 1 without Time Fixed Effects is provided in Figure 3. This figure shows the distinct negative impact with increasing proximity to the site in the time period during gravel extraction. The time period after mine closure shows the opposite, positive effect on property value with increasing proximity to the newly transformed Carburn Park.

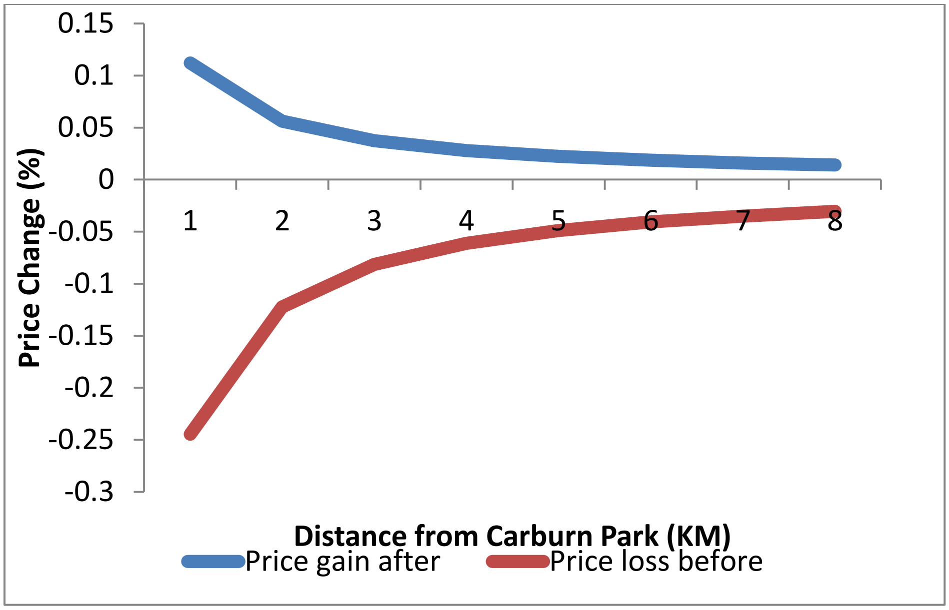

Figure 3 Percent price change in property values across varying distances from Carburn Park

Because this neighbourhood is actually composed of two separate housing types, Single Family Homes and Condos, all the models were estimated again separately for each segment of the market to investigate any potential differences. The analysis for Single Family Homes will be labelled Model 1 SFH and for Condos Model 1 CONDO. First reported are the results from Model 1 SFH in Table 5. The results of the analyses for this section are almost identical to the results reported above, likely because over 90% of the dwellings being examined fit within this category.

As with the whole data set above, the first analysis on only single family homes shows a clear distinction between a negative impact before the gravel mine ceases operations with a positive effect after. Once time fixed effects are included there is no significant effect for the before period, only a positive after. As a result of the market being composed almost entirely of single family homes, the results between this regression and the first reported are almost identical. For this reason, it is a fair assumption that the reasoning for the "before" variable becoming insignificant follows closely what was aforementioned.

Table 5 Hedonic analysis results using the basic Model 1 structure and only Single Family Homes (SFH), indicating impacts of the gravel mine before and after the mine closed interacted with inverse distance from the site

	Model 1 SFH	
Attribute	OLS[1]	TFE[2]
Inverse Distance Before	-0.13842***	0.10205
	(0.0273)	(0.0527)
Inverse Distance After	0.050122***	0.0336***
	(0.0091)	(0.0055)
Presence of Air	0.05627***	0.03340***
Conditioning	(0.0102)	(0.0098)
Waterfront	0.08276	0.14303***
	(0.0694)	(0.0425)
Presence of Basement	0.10118	0.04792
	(0.05488)	(0.0318)
Presence of Garage	0.00502	0.04239***
	(0.0129)	(0.0107)
Size of Garage	0.07085	0.04292***
	(0.0080)	(0.0064)
Deck or Balcony	0.05154***	0.0224**
	(0.0052)	(0.0042)
Area of Home	0.00231***	0.0019***
	(0.0004)	(0.0003)
Lot Size (m^2)	0.0000	0.0000
	(0.0000)	(0.0000)
No. Bedrooms	0.01256***	0.00843***
	(0.0030)	(0.0026)
No. Bathrooms	0.08775***	0.06575***
	(0.0056)	(0.0658)
Fire Place	0.06231***	0.0601***

	(0.0059)	(0.0049)
Age of House	-0.00119***	-0.00192***
	(0.0003)	(0.0002)
Constant	12.05807***	12.06713***
	(0.03402)	(0.0553)
R^2	0.66	0.76
N	6361	6361

P<0.01=***, P<0.05=**, P<0.1=*

[1]OLS = Ordinary Least Squares

[2]TFE= Time Fixed Effects

The results of the analysis change for Model 1 CONDO are different, with a positive impact reported both before and after mine closure (Table 6). Inclusion of time fixed effects change the before effect to significantly negative and much larger than the positive effect in the second time period, the opposite of the case for the single family homes segment. This result suggests that the condos in this area may be more sensitive to the activity in the gravel mine than the single family homes surrounding it. This may be because condos generally lack yard space and residents of those dwellings would rely more on the space for recreation. While the gravel mine was operating they would not have been able to access the park. This may also be because during these years several condo units were closer to the mine than the single family homes (within the 1.4 km radius), and as a result may have experienced greater property value impacts.

Table 6 Hedonic analysis results using the basic Model 1 structure and only Condos, indicating impacts of the gravel mine before and after the mine closed interacted with inverse distance from the site

	Model 1 CONDO	
Attribute	OLS[1]	TFE[2]
Inverse Distance Before	0.17082***	-0.42510***
	(0.0637)	(0.1444)
Inverse Distance After	0.03224***	0.02509**
	(0.0074)	(0.0067)
Presence of Air	0.02525	-0.01005
Conditioning	(0.0285)	(0.0245)
Waterfront	0.12494	0.1154
	(0.0140)	(0.0229)
Presence of Basement	N/A	N/A
Presence of Garage	0.33499***	0.2310***
	(0.0535)	(0.0519)
Size of Garage	0.0070	0.04929**
	(0.0288)	(0.0272)
Deck or Balcony	0.04801***	0.0152
	(0.0171)	(0.0153)
Area of Home	0.00437***	0.0036***
	(0.0005)	(0.0004)
Lot Size (m^2)	0.0000	0.0000
	(0.0000)	(0.0000)
No. Bedrooms	-0.03949***	-0.0005
	(0.0146)	(0.0134)
No. Bathrooms	0.08948***	0.06535***
	(0.0209)	(0.0654)
Fire Place	0.07022***	0.09524***

	(0.0172)	(0.0134)
Age of House	0.00796***	-0.0001
	(0.0012)	(0.0133)
Constant	11.64742***	11.94679***
	(0.0765)	(0.0917)
R^2	0.76	0.83
N	580	580

P<0.01=***, P<0.05=**, P<0.1=*

[1]OLS = Ordinary Least Squares

[2]TFE= Time Fixed Effects

2.32 Model 2 Results

A DD model was estimated in Model 2 to account for some of the limitations of the hedonic method, the results of which are presented in Table 7. As aforementioned, a 2 km treatment area was selected for the analysis. This treatment was interacted with a dummy for the second time period, after 1985 once the gravel mine has closed. The results of this analysis are approximately the same with regard to the magnitudes, signs and significances of the housing characteristics on property value as in Model 1. The DD parameter of interest, labelled 'Treatment*After', has the expected sign and significance as well. It is both positive and significant, indicating that there an impact on housing values from the gravel mine which becomes positive once it has been reclaimed into the park.

Again to test the robustness of this model time fixed effects are included. The magnitudes, signs and significance of the coefficients remain almost identical between the two models. The DD parameter also remains positive and significant though the magnitude decreased by approximately half, reducing what previously appeared to be a larger impact. Similar results in both the DD model and the DD model with time fixed effects suggests that the results from this analysis are robust, supporting the notion that the negative environmental externalities generated from gravel extraction may have had a significant impact on property values during production, but that this effect becomes positive once reclamation is completed.

Table 7 DD analysis results for Model 2 using a 2 km treatment area and 2 time periods (before and after mine closure)

	Model 2	
Attribute	OLS[1]	TFE[2]
Period 2: After	0.07019***	-0.16583***
	(0.0231)	(0.0397)
Treatment	0.01126	-0.00372
	(0.0259)	(0.0226)
Treatment *After	0.07168***	0.04379***
	(0.0262)	(0.0231)
Presence of Air Conditioning	0.05691***	0.03470***
	(0.0098)	(0.0096)
Waterfront	0.10740*	0.14472***
	(0.0570)	(0.0409)
Presence of Basement	0.12661	0.06083
	(0.0573)	(0.0357)
Presence of Garage	0.03718**	0.06930***
	(0.0129)	(0.0109)
Size of Garage	0.05924***	0.03377***
	(0.0084)	(0.0068)
Single Family House	0.12828***	0.17255***
	(0.0085)	(0.0069)
Deck or Balcony	0.05422***	0.02729***
	(0.0050)	(0.0041)
Area of Home	0.00241***	0.00197***
	(0.0004)	(0.0003)
Lot Size	0.0005	-0.0000
	(0.0005)	(0.0001)
No. Bedrooms	0.00796***	0.00515***

	(0.0030)	(0.0026)
No. Bathrooms	0.09294***	0.07176***
	(0.0054)	(0.0044)
Fire Place	0.05791***	0.05825***
	(0.0060)	0.0051)
Age of House	-0.00078***	-0.00328***
	(0.0002)	(0.0003)
Constant	11.82261***	11.94193***
	(0.0359)	(0.0455)
R^2	0.67	0.76
N	6941	6941

P<0.01=***, P<0.05=**, P<0.1=*

[1]OLS = Ordinary Least Squares

[2]TFE= Time Fixed Effects

The same process is repeated for the Single Family Home component of the market, reported in Table 8 (Model 2 SFH). The signs and significance on the housing characteristics are as expected including a positive sign on the DD parameter, though it becomes insignificant. This may because there are fewer observations, or because the SFHs are not located within 1.4 km of the mine whereas the Condos are. Within this radius immediately next to the mine, the impacts of both extraction and reclamation would be greater.

Table 8 DD analysis results for both Model 2 using a 2 km treatment area and 2 time periods (before and after mine closure) and only Single Family Homes (SFH)

	Model 2 SFH	
Attribute	OLS[1]	TFE[2]
Period 2: After	0.08542***	-0.10571**
	(0.0265)	(0.0460)
Treatment	0.01753	-0.00318
	(0.0291)	(0.0256)
Treatment *After	0.05994***	0.02803
	(0.0262)	(0.0262)
Presence of Air Conditioning	0.05437***	0.03376***
	(0.0102)	(0.0099)
Waterfront	0.13507*	0.17701***
	(0.0702)	(0.0464)
Presence of Basement	0.13136**	0.06610*
	(0.0556)	(0.0337)
Presence of Garage	0.00687	0.04136***
	(0.01297)	(0.0108)
Size of Garage	0.07081***	0.04481***
	(0.0083)	(0.0066)
Deck or Balcony	0.05031***	0.02310***
	(0.0050)	(0.0044)
Area of Home	0.00245***	0.00202***
	(0.0004)	(0.0004)
Lot Size (m^2)	0.0000	-0.0000
	(0.0000)	(0.000)
No. Bedrooms	0.01214***	0.00249***
	(0.0030)	(0.0025)
No. Bathrooms	0.08534***	0.06643***

	(0.0059)	(0.0048)
Fire Place	0.06445***	0.06189***
	(0.0062)	0.0051)
Age of House	-0.0008***	-0.00321**
	(0.0002)	(0.0003)
Constant	11.93923***	12.11109***
	(0.0355)	(0.0500)
R^2	0.64	0.74
N	6361	6361

P<0.01=***, P<0.05=**, P<0.1=*

[1]OLS = Ordinary Least Squares

[2]TFE= Time Fixed Effects

When the model is estimated using only the condo portion of the market (Model 2 CONDO), the DD parameter is again both positive and significant with and without time fixed effects, but the magnitude of the coefficient is much larger. In the case of the time fixed effects estimation, the value of the coefficient is about three higher than the value in model considering housing types supporting the notion of the higher sensitivity of condos to the activities in the gravel mine and land reclamation after. Also worth noting is that in this model, likely in part due to the few number of observations, many of the other parameters drop out of significance such as the impact of having a garage, basement or air conditioning. The number of bedrooms becomes a negatively significant parameter, contrary to common expectation. This sometimes happens as a result of the number of bedrooms not being indicative of a larger dwelling, simply meaning fitting more rooms into one of the same size. These results are presented in Table 9.

Table 9 DD analysis results for Model 2 using a 2 km treatment area and 2 time periods (before and after mine closure) and only Condos

	Model 2 CONDO	
Attribute	OLS[1]	TFE[2]
Period 2: After	-0.1239***	-0.28063***
	(0.0391)	(0.0740)
Treatment	-0.0797*	-0.07456**
	(0.0451)	(0.0331)
Treatment *After	0.11634**	0.15109***
	(0.0462)	(0.0348)
Presence of Air	0.01290	-0.01408
Conditioning	(0.0268)	(0.0231)
Waterfront	0.09385	0.06470
	(0.0248)	(0.0268)
Presence of Basement	N/A	N/A
Presence of Garage	0.40289	0.24350***
	(0.0526)	(0.0519)
Size of Garage	-0.00804	0.05071**
	(0.0319)	(0.0283)
Deck or Balcony	0.05298***	0.01521
	(0.0172)	(0.0150)
Area of Home	0.00403***	0.00243***
	(0.0006)	(0.0005)
Lot Size (m^2)	0.00000	0.0000
	(0.0000)	(0.0000)
No. Bedrooms	-0.04621***	0.01038
	(0.0146)	(0.0133)
No. Bathrooms	0.11394***	0.08351***
	(0.0210)	(0.0196)

Fire Place	0.05437***	0.07675***
	(0.0178)	(0.0133)
Age of House	0.00709***	-0.00236**
	(0.0012)	(0.0013)
Constant	11.81409***	11.85309***
	(0.0772)	(0.0771)
R^2	0.72	0.84
N	580	580

P<0.01=***, P<0.05=**, P<0.1=*

[1]OLS = Ordinary Least Squares

[2]TFE= Time Fixed Effects

To further test the robustness of these results, and because of a limitation in the data with regard to the availability of data prior to the mine was built in comparison to many years available after, the regressions were run again using only the data provided up to 1995 rather than up to 2010. Table 10 shows the results of Model 1, which once again show a negative impact before reclamation which is reversed after. The negative impact is, however, much smaller and insignificant in this scenario. In contrast, the positive effect of reclamation has more than doubled, perhaps indicating that the positive impact is stronger in the early years since reclamation than later. In the fixed effects scenario, the before time period is insignificant as well, while the positive impact has once again doubled since the original model. The signs and significances of the property attributes are all appropriate, while the magnitudes of the values have in many cases decreased marginally.

Table 10 Hedonic analysis results using the basic Model 1 structure indicating impacts of the gravel mine before and after the mine closed with observations up to1995

	Model 1	
Attribute	OLS[1]	TFE[2]
Inverse Distance Before	-0.03556	0.05175
	(0.0136)	(0.0539)
Inverse Distance After	0.11270***	0.08031***
	(0.0104)	(0.0080)
Presence of Air	0.08251**	0.07351**
Conditioning	(0.0320)	(0.0031)
Waterfront	0.04942	0.05393*
	(0.0758)	(0.0310)
Presence of Basement	N/A	N/A
Presence of Garage	0.00554	0.05238*
	(0.0212)	(0.01769)
Size of Garage	0.08120***	0.05298***
	(0.0125)	(0.0101)
Deck or Balcony	0.05345***	0.03234***
	(0.0076)	(0.0042)
Area of Home	0.00160***	0.0014***
	(0.0005)	(0.0003)
Lot Size (m^2)	N/A	N/A
No. Bedrooms	0.02751***	0.01783***
	(0.0049)	(0.0041)
No. Bathrooms	0.0774***	0.07066***
	(0.0056)	(0.0069)
Fire Place	0.09523***	0.08976***
	(0.0078)	(0.0065)
Age of House	-0.00304***	-0.0044***

	(0.0004)	(0.0003)
Constant	11.80073***	11.88994***
	(0.0503)	(0.0624)
R^2	0.60	0.72
N	2720	2720

P<0.01=***, P<0.05=**, P<0.1=*

[1]OLS = Ordinary Least Squares

[2]TFE= Time Fixed Effects

Table 11 provides the results for Model 2 once again only using observations up to 1995. In all of the following scenarios, the DD parameter is both positive and significant, corresponding with the previous results. The signs, significances and magnitudes in this model correspond closely to the previous results as well, however the presence of a basement and lot size both drop out, and the presence of a garage becomes insignificant. Although there are a few marginal changes, the results from this analysis have largely remained the same, indicating their robustness.

Table 11 Hedonic analysis results using the basic Model 1 structure, indicating impacts of the gravel mine before and after the mine closed with observations up to 1995

	Model 2	
Attribute	OLS[1]	TFE[2]
Period 2: After	0.01117	-0.18019***
	(0.0207)	(0.04003)
Treatment	-0.00448	-0.01309
	(0.0233)	(0.0214)
Treatment *After	0.08133***	0.05929***
	(0.0245)	(0.0224)
Presence of Air	0.06586*	0.06115*
Conditioning	(0.0336)	(0.0032)
Waterfront	0.12609***	0.11021***
	(0.0702)	(0.0206)
Presence of Basement	N/A	N/A
Presence of Garage	0.00445	0.03338*
	(0.0216)	(0.0181)
Size of Garage	0.08906***	0.05818***
	(0.0131)	(0.0105)
Deck or Balcony	0.05940***	0.03643***
	(0.0079)	(0.0044)
Area of Home	0.0018***	0.00147***
	(0.0006)	(0.0005)
Lot Size (m^2)	N/A	N/A
No. Bedrooms	0.02354***	0.01460***
	(0.0050)	(0.0025)
No. Bathrooms	0.08114***	0.07332***
	(0.0083)	(0.0072)

Fire Place	0.09808***	0.09209***
	(0.0084)	(0.0070)
Age of House	-0.0035***	-0.0048**
	(0.0004)	(0.0004)
Constant	11.80493***	11.91516***
	(0.0568)	(0.0588)
R^2	0.59	0.71
N	2720	2720

P<0.01=***, P<0.05=**, P<0.1=*

[1]OLS = Ordinary Least Squares

[2]TFE= Time Fixed Effects

In summary, both models demonstrate an impact from the gravel mine on the property values surrounding it which are summarized in Table 12.

Table 12 Summary of key results from Model 1 and Model 2 for the regressions using the full sample, single family homes only, and condos only

	OLS[1]		TFE[2]	
	Before (IDB)	After (IDA)	Before (IDB)	After (IDA)
Model 1				
Full Sample	Negative, Significant	Positive, Significant	Not Significant	Positive, Significant
SFH	Negative, Significant	Positive, Significant	Not Significant	Positive, Significant
CONDOS	Positive, Significant	Positive, Significant	Negative, Significant	Positive, Significant
	DD Parameter (Treatment *After)		DD Parameter (Treatment* After)	
Model 2				
Full Sample	Positive, Significant		Positive, Significant	
SFH	Positive, Significant		Not Significant	
CONDOS	Positive, Significant		Positive, Significant	

[1]OLS = Ordinary Least Squares

[2]TFE= Time Fixed Effects

Model 1 shows a negative effect during extraction, however this becomes insignificant when time fixed effects are included. The impact of reclamation remains positive in significant in all scenarios however, indicating its robustness. In this analysis the impacts of extraction do not generate consistent significant results, though there is a consistent positive and significant impact generated by reclamation. The sensitivity of the results during extraction could possibly be due to the limited number of observations available during that time period, the small numbers of houses between 0-1.4 km of the mine, or the unpredictability of preferences of the homeowners. There may also be omitted variables relating to macroeconomic conditions that is causing the difference between the OLS and TFE models. All of the signs and significances from this model are as expected and make sense. When the observations are divided into single family homes and condos, the single family homes analysis had almost identical results to the original full analysis The condos were the only properties which indicated a negative impact during extraction when time fixed effects are included, although they accounted for only a small portion of the sample.

Model 2 was a DD analysis which can be used to correct for some of the shortcomings of hedonic analyses. In this research it was used to check the robustness of the results from Model 1. Model 2 confirmed the findings of Model 1, indicating a significant positive gain from the reclamation of the gravel mine in 1986.

As a result of these analyses all providing indication of a negative impact of the gravel mine on proximal households and more significantly the positive impact of reclamation, the location choice of this mine is called into question. Had the mine been further away, perhaps the negative impacts on those properties never would have existed. As aforementioned, gravel operators argue that transporting gravel is too expensive and increases their environmental footprint dramatically. The next stage of analysis will take advantage of the results from these models, and use them in the construction of a gravel mine simulation. This simulation will be used to compare the costs of transportation, both direct and from externalities, with the social cost of extraction near households to determine if it is in fact more cost effective to maintain a mine so close to its market or if it would make more sense to mine further away.

3. Gravel Mine Simulation

3.1 Introduction and Background

Mining of sand and gravel is unwelcome near neighbourhoods and communities because of the negative externalities associated with it such as increased traffic, road damage, noise, and dust. Because of its low unit-value in comparison to high transportation costs it is frequently extracted in close proximity to its intended market. This often means that gravel pits are located within urban centers where new communities are being developed. In the hedonic property value analysis described above, a significant downward pressure on property values is measurable until extraction ceases. Furthermore, gravel mining companies have argued that by situating their operations closer to the market they are actually reducing their environmental foot print by decreasing the amount of traffic and kilometers their product must travel. According to the results of the previous analysis however, there is significant evidence suggesting that the externalities from a nearby mine are in fact generating a negative impact on the property values in the surrounding neighbourhood, or that reclamation will generate a positive effect. The purpose of this simulation is to compare the costs of transportation with the estimated cost of the externalities from the mine to compare the cost effectiveness of gravel extraction at greater distances from its market and to evaluate the impact of more rapid reclamation at the site.

Using the empirical hedonic price model findings in conjunction with gravel prices, freight travel costs and estimated values for the additional negative externalities generated from transportation, a simulation model of a hypothetical gravel mine is created. By capturing the externality effects in the simulation, the study compares mine operations with and without the incorporation of various externality effects. Without taking into account how social costs such as local property value effects, the high cost of transporting gravel is cost inefficient from the perspective of the mine operator. The model attempts to calculate the magnitude of the value of the externality when aggregated over an entire community to examine whether incorporating the social costs of extraction in addition to the private costs in the decision making process may result in it being more effective to move the mine away from its market.

The simulation model analysis is also an attempt examine the issue of optimal reclamation timing. If the negative externality of a mine extends through time until reclamation takes place, then reclaiming sooner would have significant positive impact on the values of surrounding households. Currently Alberta is regulated by guidelines that do not provide strict reclamation timing schedules to mine operators. Furthermore, municipalities stand to gain tax revenues generated by property value increases once reclamation takes place. Demonstration of this fact may provide incentives to the municipalities to require timely reclamation to take place.

3.2 Literature Review

The low unit-value cost of gravel is one of the main barriers for relocating mines further from urban centers. Jaeger discusses the costs of relocating aggregate mines in the context of a program in Oregon to protect high-value farmland. Jaeger finds that the true cost of relocating gravel mines from the farmland being protected is equivalent to a $40,000.00 per acre cost, compared with the market value of that same farmland at $2000.00 per acre. Although farming culture in this region of Oregon will benefit from the policy, this price differential signals it to be extremely economically inefficient. Values used to calculate per-ton-mile cost of transporting gravel from Jaeger's paper are used in this simulation.

Aside from the direct costs of increasing the distance of aggregate transport, there are other external costs that must be considered. These costs include but are not limited to; health impacts, number of traffic accidents, noise, dust and road damage. In terms of health related costs, a report for Transport Canada by Marbek Resource Consultants Ltd. (2007) touches on the overall costs of air pollution from transportation in Canada. This report examines costs associated with several health conditions including acute exposure mortality, adult bronchitis, cardiac emergency room visits, asthma symptom days, etc. Muehlenbachs and Krupnick (2013) examine the connection between increased traffic from increasing Shale Gas development in Pennsylvania and traffic accidents. Their preliminary research indicates that heavy-duty truck accidents increase by 2% with each additional well drilled per month, and that fatalities increase 0.6%. Additionally, the Center for Disease Control and Prevention has found that of all of the fatalities related to oil and gas extraction in the U.S., approximately 27% of them are highway motor-vehicle accidents. In his hedonic analysis of the impact of traffic noise on property values, Wilhelmsson (2010) finds that single-family houses sell for approximately 30% less if they are located near a noisy road. Delucchi and McCubbin (2010) summarize the costs associated with the externalities from transportation, including a per-ton-mile amount associated with freight trucking in the literature. The amounts from Delucchi and McCubbin's (2010) summary are averaged and used for this analysis.

Harris (1999) cites the work of Peiser and Smith (1985) in his analysis of how property values change based on socioeconomic and racial factors. Harris (1999) uses the methods of Peiser and Smith (1985) to annualize property values to perform his study. This same method will be employed in the simulation below to enable an accurate comparison and analysis of yearly costs from the various sources.

3.3 Methods

3.31 Calculating the Aggregated Externality Effect

To calculate the aggregate impact of the externality from resource extraction on the houses in the area, the values from the full sample scenario of Model 1 OLS in the previous section are used. This model is used because it provides coefficient values for both the time period during extraction as well as once reclamation took place. These values allow for an analysis of both scenarios within the following simulation, the negative impact of extraction on property values and the positive impact of reclamation. Although the results of Model 2's DD analysis could be considered more reliable to use in the simulation analysis, the results of Model 1 were used in large part to decrease the complexity of the required calculations. The steps to carry out this calculation are as follows;

- Using ArcGIS, the number of houses in gradually increasing intervals from the site are calculated during the years of production from 1982-1985.
- The coefficients for the different variables, except inverse distance, in the previous hedonic analysis are all multiplied by their means within the sample and summed.
- The coefficient on the inverse-distance dummy variable for before mine closure is multiplied by inverse distances at various intervals (1/0.5 km, 1/1 km, etc.), and added to the rest of the equation.
- This process gives a value for natural log of the value of the houses at various intervals so that the impact at different intervals can be determined.

- Exponentiation of this value and subtracting the values at the different intervals gives a value for the change in property value per house depending on location.
- This per house amount is then multiplied by the number of houses in the given interval at the time period to generate the aggregate impact.
- Finally, this totally amount is converted to annual value dollars by multiplying these values by 0.0785 (Harris 1999).

Several hundred new houses were built during the period of operation, resulting in an increasing aggregate impact of the externality through time. Table 13 provides the number of houses in each 0.5 km increment from the mine.

Table 13 Number of houses in each 0.5 km interval from Carburn Park

Year	0.5km	1km	1.5km
1982	1	263	312
1983	4	469	312
1984	8	588	316
1985	9	619	316
1990	193	1063	691
1995	312	1181	1227
2000	313	1187	1261
2005	314	1187	1261
2010	314	1187	1261

3.32 Transportation Costs

In order to calculate the cost of transporting the resource, it is first important to estimate the amount of gravel extraction of the years the mine was developed. This was done in two ways, described as Scenario 1 and 2 below;

3.321 Scenario 1 Costs

In lieu of the availability of the actual output of gravel at this mine, the quantities from a mine comparable in size and location were used for comparison (Badke Consulting Ltd. 2012).

These quantities extracted, approximately 27 500 tons annually or 82 500 tons over the life of the mine, are reported in Table 14. Though both mines covered a similar land area however, it is recognized as a significant assumption that both had the same sized gravel deposit.

Table 14 Approximate annual gravel output from a comparable gravel mine to Carburn Park in terms of size, duration of extraction and location (Badke Consulting Ltd. 2012.)

Month	Tons	Monthly Trips	Daily Trips
January	0	0	0
February	550.61	14	1
March	550.61	14	1
April	2202.46	57	3
May	2202.46	57	3
June	3303.69	86	4
July	5506.15	143	7
August	6056.76	157	8
September	4404.92	114	6
October	2753.07	71	4
November	0	0	0
December	0	0	0
Total Yearly	**27530.75**	**714**	

3.322 Scenario 2 Costs

Another method for estimating the amount of gravel deposited is by using a proxy for the amount of aggregate required to build an average home in Scenario 2, approximately 120 tons (Rogers Group Inc.), and multiplying it by the number of new houses constructed in the subdivision over the life of the mine. The amounts calculated in this way are reported in Table 15, and amount to approximately 109 000 tons total over the life of the mine, and are close to the quantities measured using the area based method described above. Scenario 2 requires the assumption that extraction at Carburn Park was solely for the purpose of developing the surrounding subdivision.

Table 15 Total amount of aggregate required over the period of operation of the mine to construct the new subdivision surrounding it

Year	Total Tons of Aggregate Required for Construction of New Houses
1982	55200
1983	39000
1984	15240
Total	**109440**

An estimation of the cost of transporting gravel from a further location is then calculated. These numbers are estimated to provide a comparison with the externality impact on housing property values to identify which value is greater. This cost was calculated at the maximum distance a gravel mine would likely be developed in Alberta from its market, about 42 KM (Richards and Peel 2003). Per ton-mile (tm) cost is estimated using the values from Jaeger's (2006) article at $0.21/tm, which has been converted, as have all other values, to the base year of 2007 of the Housing Price Index.

This value only accounts for the direct cost of transportation such as fuel and wear and tear on freight vehicles. Associated with increased traffic are a number of other externalities, such as those from congestion, accidents, pollution, etc. Delucchi and McCubbin (2010) estimate the various externality costs associated with freight transport by compiling those available in the literature. The ranges of the values they provide in their article are summarized in Table 16 below. These values are summed into a single value for per ton-mile in each case, considering the lowest, average and highest freight cost recorded in Delucchi and McCubbin's (2010) study. To evaluate the sensitivity of the results, transportation costs are calculated at each one of these levels. These additional externality costs are calculated once again at a 42 km distance, and added to the value reported above. The subsequent values are considered the total cost of the additional transportation, which will be compared to the impact of gravel extraction on housing values. These transportation cost, reported in per ton-miles, are then multiplied by the tons of aggregated estimated to have been extracted in both scenarios.

Table 16 Range of costs of different externalities associated with gravel freight transport (Source: Delucchi and McCubbin 2010, pp. 24)

Externality Type	Lowest Freight Cost (per ton-mile in 2007 cents)	Average Freight Cost (per ton-mile in 2007 cents)	Highest Freight Cost (per ton-mile in 2007 cents)
Congestion Delay	0.55	0.55	0.55
Accident	0.11	0.97	2.04
Air pollution (health)	0.10	9.51	19.11
Climate change	0.02	3.00	6.03
Noise	0.00	2.71	5.42
Water Pollution	0.00	0.02	0.05
Energy Security	0.22	0.32	0.86
Total	**1.01**	**17.08**	**34.07**

A sensitivity analysis was then performed on the distance to the mine used in the calculation to determine at what distance the transportation costs begin to outweigh the property value impacts. To ascertain how the externality would have magnified over time, it is calculated as if reclamation never happened until the most recent data available in 2010 as well. To better understand the positive effect of reclamation, the benefit of reclaiming one year earlier is reported. Finally, assuming that the positive impact generated from reclamation could be considered the value change that the houses would have experienced had extraction never occurred, a comparison of foregone benefits and transportation costs is reported.

3.4 Results

3.41 Scenario 1 Results

The annual transportation costs during extraction, both direct and externality costs when calculated at 42 km, are significantly lower than the externality costs generated from gravel extraction that affect nearby households. The estimates calculated when using the values from the comparable mine are presented first in Table 17 below, as well as visually in Figure 4.

Table 17 A comparison of the freight transportation cost of gravel to 42 km based on hypothetical mine output and the externality cost of extraction on surrounding households

Year	Total Negative Externality Cost Calculated in Annual Value	Total Transportation Costs during Production to 42 km (lowest $tm)	Total Transportation Costs during Production to 42 km (average $tm)	Total Transportation Costs during Production to 42 km (highest $tm)
$1,982	$2,242,960	$317,073	$548,864	$793,332
$1,983	$3,377,625	$224,019	$387,784	$560,506
$1,984	$4,078,311	$87,540	$151,534	$219,028
$1,985	$4,257,407	$0	$0	$0
Total	$13,956,304	$628,632	$1,088,182	$1,572,866

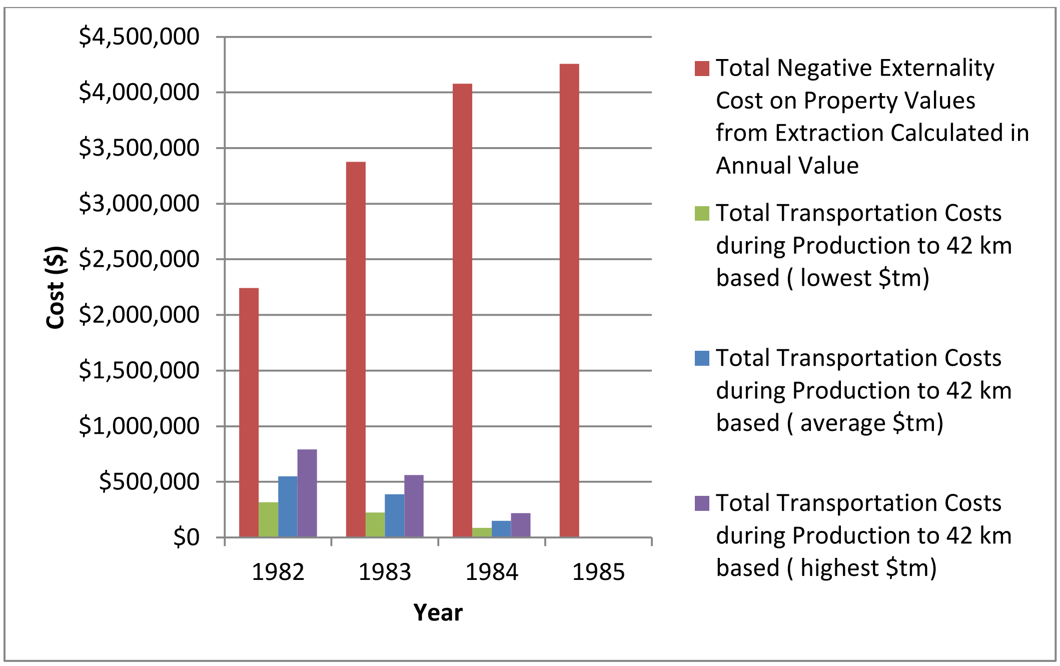

Figure 4 A comparison of the freight transportation cost of gravel to 42 km based on hypothetical mine output and the externality cost of extraction on surrounding households

The distance the mine would have to be from the market for the transportation cost to remain equal to the externality cost of extraction would be between 782 km away using the highest freight cost and 1957 km away using the lowest by the final year of extraction in 1984. The values of these costs are reported in Table 18.

Table 18 Distance mine must be from market for transportation costs to equal externality cost of gravel extraction

Year	Distance that must be travelled (Low Cost Scenario) (KM)	Distance that must be travelled (Average Scenario) (KM)	Distance that must be travelled (High Cost Scenario) (KM)
1982	297	172	119
1983	633	366	253
1984	1957	1130	782

3.42 Scenario 2 Results

In the second scenario, where a proxy is used to estimate how much aggregate was required based on the number of houses constructed, the values do not differ much from the first scenario presented above. Table 19 shows that as a result of a larger amount of gravel being extracted, the transportation costs have increased by approximately $200,000 relative to Scenario 1. This increase makes the cost of transportation more comparable to the externality cost of extraction affecting properties, particularly in the first year when more houses were built, but still amounts to approximately only one fifth of the property value impact. As more houses are built and the externality cost of extraction continues to grow, and in this scenario the transportation cost is decreasing as fewer houses are being built. This makes it increasingly less cost effective to maintain the gravel mine in such close proximity to its market, as visualized in Figure 5. To make transportation costs equal the externality cost in this scenario, the resource would have to travel between approximately 400 and 1000 km in the last year of extraction depending on how the calculation is performed (Table 20).

Table 19 A comparison of the freight transportation cost of gravel to 42 km based on proxy for quantities required to construct new houses and the externality cost of extraction on surrounding households

Year	Externality Cost of Gravel Extraction	Total Transportation Costs during Production to 42 km based (lowest $tm)	Total Transportation Costs during Production to 42 km based (average $tm)	Total Transportation Costs during Production to 42 km based (highest $tm)
1982	$2,242,960.36	$158,294	$273,868	$396,059
1983	$3,377,625.10	$158,294	$273,868	$396,059
1984	$4,078,311.33	$158,294	$273,868	$396,059
1985	$4,257,407.09	$0	$0	$0
Total	$13,956,304	$474,882	$821,605	$1,188,177

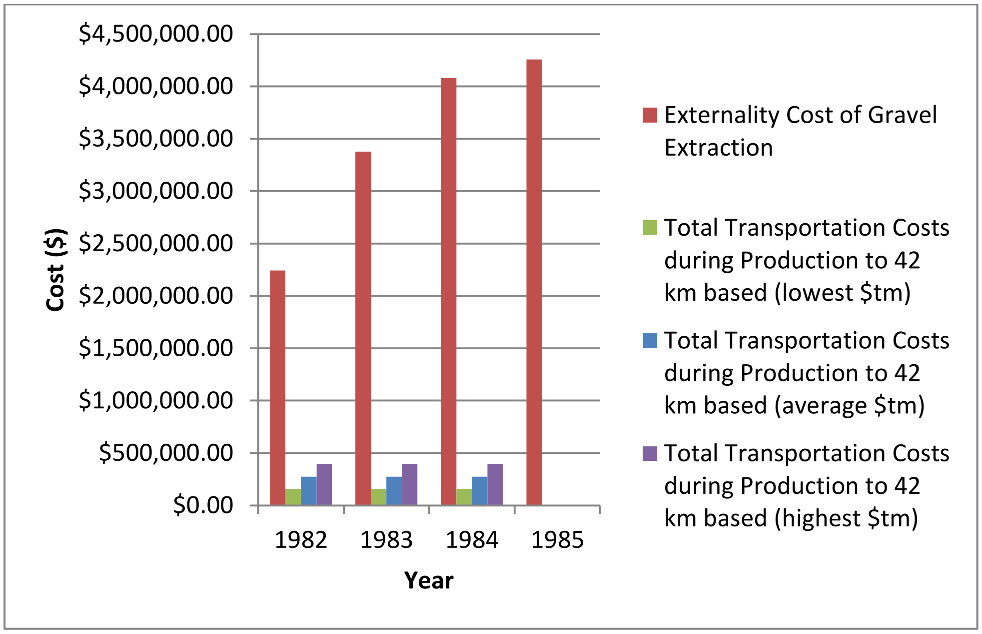

Figure 5 A comparison of the freight transportation cost of gravel to 42 km based on hypothetical mine output and the externality cost of extraction on surrounding households

Table 20 Distance mine must be from market for transportation costs to equal externality cost of gravel extraction

Year	Distance that must be travelled (Low Cost Scenario) (KM)	Distance that must be travelled (Average Scenario) (KM)	Distance that must be travelled (High Cost Scenario) (KM)
1982	595	143	238
1983	896	218	358
1984	1082	265	432

In the second scenario, where a proxy is used to estimate how much aggregate was required based on the number of houses constructed, the values do not differ much from the first scenario presented above. Table 19 shows that as a result of a larger amount of gravel being extracted, the transportation costs have increased by approximately $200,000 relative to Scenario 1. This increase makes the cost of transportation more comparable to the externality cost of extraction affecting properties, particularly in the first year when more houses were built, but still amounts to approximately only one fifth of the property value impact. As more houses are built and the externality cost of extraction continues to grow, and in this scenario the transportation cost is decreasing as fewer houses are being built. This makes it increasingly less cost effective to maintain the gravel mine in such close proximity to its market, as visualized in Figure 5. To make transportation costs equal the externality cost in this scenario, the resource would have to travel between approximately 400 and 1000 km in the last year of extraction depending on how the calculation is performed (Table 20).

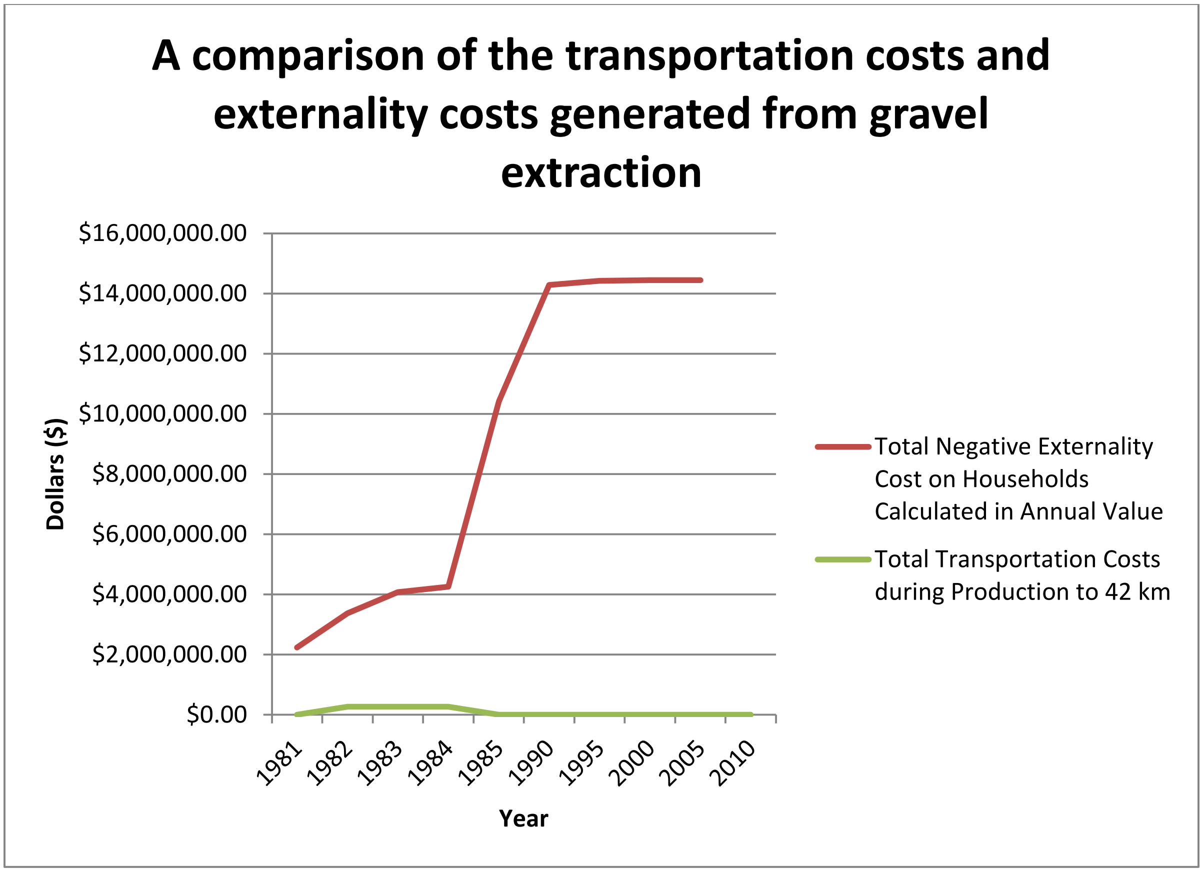

Figure 6 A comparison of the transportation costs and externality costs generated from gravel extraction until 2005

Finally, Table 21 is a summary of the estimated loss in tax revenue by the City of Calgary as a result of the gravel extraction. Though individually not a large value with reference to the total budget of a city during the years of extraction, if reclamation had failed to occur, this number would have increased substantially as did the number of houses in the community over the next 25 years.

Table 21 Municipal tax revenue loss as a result of gravel extraction from 1982-1984, and theoretical loss until 2010 based on houses up to 1.5 km away

Year	Municipal
1982	$7,593.43
1983	$11,434.90
1984	$13,807.23
1985	$14,413.59
1990	$35,253.21
1995	$48,370.25
2000	$48,838.12
2005	$48,889.68
2010	$48,889.68

3.43 Foregone Positive Benefit Results

These values for the simulation above are calculated using a coefficient value that becomes insignificant once time fixed effects were included in the model. Though Messer et al (2006) report similar results without having used time fixed effects, it was also deemed pertinent to examine the positive impacts generated from reclamation in another way. By using a hypothetical scenario where reclamation occurred one year earlier in 1984, it is possible to use the positive and significant values generated in Model 1with TFE to examine the benefits of reclaiming a mine more rapidly. The same steps as above were followed, but instead with the coefficient values for the time period after reclamation to calculate what the property values would have been in 1984 had reclamation occurred then. The negative externality value associated with the mine still being open is then subtracted from the positive value associated with reclamation to calculate the total value that would have been added to the approximately 1000 homes in the area at that time. This difference amounts to approximately $8,582,063 in additional value to the households (Table 22).   Nonetheless, this number shows how significantly timely reclamation impacts the value of properties.

Table 22 Property value increase from reclaiming one year earlier

Year	Total Externality on Households in 1984 Calculated in Annual Value	Total Positive Externality for Households Generated from Reclamation in 1984 in Annual Value	Total Benefit of Reclamation One Year Earlier
1984	-$4,078,429	$3,816,149	$7,894,578

Another way to consider the problem in the context of this simulation is to consider foregone positive gains to property value during the years of extraction, instead of directly considering the negative impacts generated from extraction. This once again utilizes the more robust positive result reported in Model 1 as a result of reclamation. In doing this analysis, the assumption is made that the positive gains to property values post reclamation in fact reflect what the property values would have been during the time period of extraction had it never occurred. This was done in both the Scenario 1 and Scenario 2 contexts, as reported in Table 23, Figure 7, Table 24 and Figure 8.

Table 23 A comparison of the freight transportation cost of gravel to 42 km based on hypothetical mine output and the foregone positive benefits on property values of never having extracted on surrounding households

Year	Foregone Positive Benefit of Avoiding Damages	Total Transportation Costs during Production to 42 km based (lowest $tm)	Total Transportation Costs during Production to 42 km based (average $tm)	Total Transportation Costs during Production to 42 km (highest $tm)
1982	$2,210,190.08	$158,294	$273,868	$396,059
1983	$3,246,543.99	$158,294	$273,868	$396,059
1984	$3,816,149.09	$158,294	$273,868	$396,059
1985	$3,962,474.58	$0	$0	$0
Total	$13,235,358	$474,882	$821,605	$1,188,177

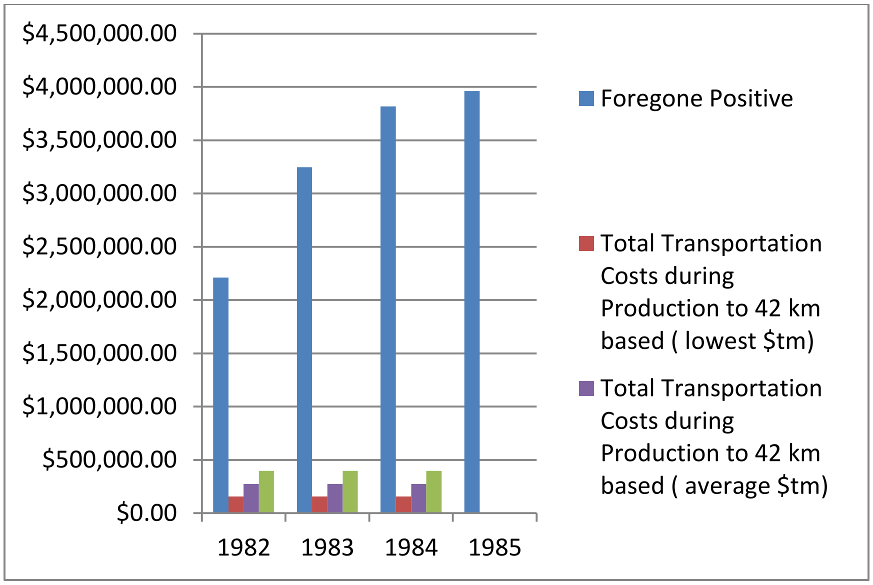

Figure 7 A comparison of the freight transportation cost of gravel to 42 km based on hypothetical mine output and the foregone positive benefits on property values of never having extracted on surrounding households

When the analysis is conducted once again using the hypothetical mine output in comparison with the foregone positive benefits, the difference between transportation costs and the foregone positive benefit is slightly smaller than those previously reported in sections 3.41 and 3.42 (Table 23 and Figure 7). Table 24 and Figure 8 provide the results of this analysis when using the proxy value for the amount of gravel the mine would have extracted below.

Table 24 A comparison of the freight transportation cost of gravel to 42 km based on proxy for quantities required to construct new houses and the foregone positive benefits on property values of never having extracted on surrounding households

Year	Foregone Positive	Total Transportation Costs during Production to 42 km (lowest $tm)	Total Transportation Costs during Production to 42 km (average $tm)	Total Transportation Costs during Production to 42 km(highest $tm)
1982	$2,210,190	$317,073	$548,864	$793,332
1983	$3,246,544	$224,019	$387,784	$560,506
1984	$3,816,149	$87,540	$151,534	$219,028
1985	$3,962,475	$0	$0	$0
Total	$13,235,358	$628,632	$1,088,182	$1,572,866

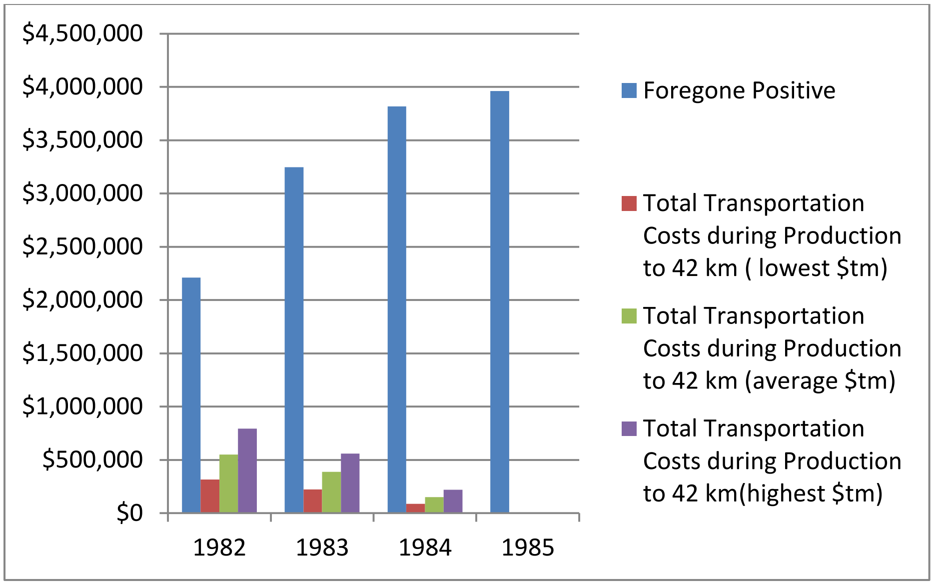

Figure 8 A comparison of the freight transportation cost of gravel to 42 km based on proxy for quantities required to construct new houses and the foregone positive benefits on property values of never having extracted on surrounding households

The results again reveal a smaller difference between transportation costs and the estimated positive benefit foregone as a result of extraction, though less though than when calculated using the hypothetical mine output. These results again contradict the argument held by gravel mine operators that continuing to mine in close proximity to the market reduces their environmental footprint.

3.5 Discussion of Simulation Analysis

In Alberta, gravel mines are typically no further than 42 km away from their intended market (Richards and Peel 2003). This is largely because it is not perceived to be cost effective to transport gravel further due to the combination of the weight of the resource and its low per-unit value. Furthermore, the gravel industry has claimed that they reduce their environmental footprint by extracting closer to their market by reducing the amount of trucking required. The results of this simulation suggest that when accounting for the social costs associated with extraction, attaining gravel from mine that is a greater distance away may be more cost effective. This finding is consistent in both simulation calculations, where the amount of gravel is estimated first by using values from a comparable mine and second by using a proxy based on how many houses were built each year. Although in Scenario 2 the cost of transportation is closer to the social cost of extraction than in the Scenario 1, it still only accounts for less than half of the social cost in each year. Furthermore, when considering this problem instead in the context of foregone benefits as a result of extraction, it becomes cost effective to transport the aggregate to even further distances. Due to the consistency of the results from all of the scenarios, they can be considered robust in nature.

Although it is traditionally considered that the various aspects of trucking the resource have the largest impact on communities, these findings suggest the opposite. There is another externality generated by the mine that outweighs those generated by trucking, for example the aesthetic value. This research thus challenges the common perception that the low unit-value of gravel in combination with its high transportation cost necessitates its extraction in close proximity to its market.

There are some important limitations to take into account regarding this analysis. For example, the model does not consider the individual per tonne tax that municipalities can charge gravel companies to balance some of the negative impacts of the hauling, such as increased traffic and how that impacts road networks. This tax can vary by each municipality, and is something gravel companies may or may not be liable to pay. Companies are sometimes required to maintain the main roads and highways surrounding the mines they use as main access routes for their hauling trucks. The nature of gravel mining has changed over the years, moreover. For example, since 1985 it has become increasingly common practice to construct noise controlling berms around pits to reduce the disruption to nearby communities.

Furthermore, when calculating the externality cost beyond the year 1985, the model is assuming that the negative externalities from extraction such as dust and noise are transcending through time when in fact they would have ceased. Although the negative aesthetic value would have continued to generate a negative externality had reclamation not occurred, the model is likely overestimating this externality. The absence of the actual costs of reclamation in this analysis is also limiting, not allowing for a true cost/benefit analysis of the earlier reclamation. Another consideration not taken into account is that the impacts of trucking would have been higher along major trucking routes. Due to the limited nature of the data, it was not feasible to try to account for the varying effects of trucking throughout the community. It could have been interesting to do the simulation analysis based on only the condos in the community, as they reported significant negative impacts generated during the time of extraction even with time fixed effects. However, they represent such a small percentage of the sample size that it again would not have provided an accurate comparison of the costs.

Finally, by using the values from Model 1, the results of all of the simulation analysis are somewhat compromised. Model 1's results become insignificant when time fixed effects are included, indicating their sensitivity. Though there are several data limitations that may explain this, placing confidence in such sensitive results may subsequently lead to inaccuracy and reliability in the simulations analysis results. Even the positive value from Model 1 to calculate foregone positive benefits due to extraction cannot be considered as robust as the positive value consistently generated in Model 2. In the DD analysis of Model 2, the DD parameter consistently indicates the benefits due to reclamation activities on the property values in the surrounding neighbourhood. The results from this model could have been utilized in a similar method to the analysis performed in the latter part of the simulation to demonstrate foregone additional increases to property values during the period of extraction. These estimated values could have then been compared to the costs of transportation to provide a basis for comparison. However, because the DD parameter does not contain information about the inverse distance to the site as results from Model 1 do, it would have been difficult to evaluate how the property values are affected with relation to their distance from the gravel mine. The analysis would have generated a value not for how those foregone property values change with distance to the site, but a consistent value for all households in the treatment area. Therefore, although the DD parameter provides more robust results with regard to the positive impact on property values generated from reclamation, using those values would not provide the same intuitive results of property values varying with distance to the site. Model 3 in the appendix does calculate the DD parameter with considerations for inverse distance to the site, but does not provide the same positive and consistent results as those in Model 2.

The results of this simulation analysis have potential policy implications. One such implication has to do with reclamation timing. If it is accurate that the negative impacts of extraction continue through time beyond mine closure until reclamation, then the incentive to reclaim becomes much greater. The estimated benefit from reclaiming one year earlier was calculated to be approximately $8,000,000. Again, as the number of houses increase in an area, that benefit would continue to grow as it counters the negative impacts that would have otherwise existed. For the City of Calgary, it would mean a higher potential tax-base. If reclamation had not been completed so promptly, this negative impact could have continued to grow, creating an even larger negative impact on tax revenue as the population in the area increased. This monetary incentive could encourage more timely reclamation strategies.

Currently the Province of Alberta's *Conservation and Reclamation Regulation* under the Environmental Protection and Enhancement Act (EPEA) does not provide strict reclamation timeline regulation. Instead, the Director provides standards, criteria and guidelines for mine operation on a case by case basis. If for example the City of Calgary understood the true extent of negative impact that would be generated in the absence of reclamation, it could push to have necessary reclamation deadlines included in any future approvals passed. They may also choose to reject any future gravel pits on municipal land to prevent depression of property values because of extraction.

4. Summary, Conclusions and Limitations

The results of the analyses in this research provide further evidence to the already existing literature on the property value impacts from aggregate resource extraction. The externalities generated from extraction would have included dust, noise, increased traffic, deteriorating road conditions, as well as the loss of the aesthetic value of what was once agricultural land on the bank of the Bow River. The results of the hedonic property analysis in Model 1indicate there is a downward pressure on property values for those households surrounding the gravel mine that once existed in what is now Carburn Park. This impact is not robust however, as it becomes insignificant when time fixed effects are included in the analysis. In 1985 production ceased and the gravel mine was converted into a park as was the agreement with the City of Calgary when the approval was issued. By 1986 the new Carburn Park was announced by Ralph Klein signalling the full reclamation of the site, though it did not receive a reclamation certificate until 2005. Model 1's results consistently provide a positive and significant impact to property values generated from reclamation activities in all scenarios investigated. In the context of this model, the positive impacts indicate increasing property values with proximity to site. As a result of the positive impacts, there may be a significant incentive to planners to incorporate strict reclamation timelines into any approvals issued for gravel mines. These results do not align with the results found in the hedonic literature such as the hedonic price analysis of the impact of sour gas wells and shale gas development on property values, which find consistent negative impacts as a result of industrial activities (Boxall et al 2005, Muehlenbachs et al 2013).These results also conflict with those reported by Erickcek (2009) who stated that the negative impacts on property values from aggregate extraction exist indefinitely. They further do not support the theory of stigmatization effects produced by Messer et al (2006).

The results of this analysis were evaluated for their robustness using time fixed effects (TFE). By including these effects, the variable representing the time period before reclamation became positive and not significant, thus indicating its sensitivity. When examining only the condos in that area, however, the opposite is true and the negative effect is in fact much larger than when considering the whole data sample. After analyzing the properties of the data set, it was found that the majority of the properties immediately next to the mine were in fact condos, while single family homes were situated further away. The reason the whole data sample may have been experience the sensitivity around the IDB or ‘before’ parameter may be because there are few single family home sale observations in the area directly next to the park (less than 1.4 km) prior to 1985, while they make up about 90% of the total observations. Another potential reason for this sensitivity is the lack of observations prior to 1985. Only approximately 400, or 6%, of the observations in the data are housing sales occurring before mine closure in 1985. Finally, the nature of preferences of the individuals moving into that area at that time is unknown, and may have countered expectations. For example, they may have been aware that although there was an operating gravel mine, there was a plan to immediately reclaim it. This may have caused the positive coefficient value in the first time period as those individuals anticipated positive externality values once reclamation completed, or were not affected by any externalities generated during extraction.

To further test the robustness of these results, a DD model was estimated using a treatment area of 2 km and two time periods; before and after 1985. Both when running the model without and then with TFE, the DD parameter was positive and significant as predicted in almost all scenarios. Using the DD model provided even stronger evidence to support the existence of a significant positive impact from the closure of the mine in 1985.

This elimination of the negative effect potentially generated during the extraction period could have significant policy implications. If the negative impact on property values transcends time until reclamation takes place, it means that up to that point there will be a significant social cost imposed upon residents. Persisting for years, this loss would become gradually larger as the number of houses in the area increase. This could have a significant impact on the total tax revenue for a municipality over time. Because this impact because insignificant over time, however, it is difficult to estimate with certainty the true negative impact generated from extraction.

The positive impact after reclamation is more consistent in the analysis, remaining positive and significant in all of the scenarios tested. Reclaiming the gravel pit into a park has quality of life impacts for residents, particularly those residing in condos that likely rely more heavily on public green space than those dwellers in single family homes with their own backyards. By utilizing this consistent result, it was possible to demonstrate the potential benefits to more rapid reclamation and the foregone positive benefits as a result of extraction.

The simulation model provided results that contrast with common perceptions about gravel freight transportation. Property value impacts were included alongside the expected revenue and transportation costs, both direct and externality costs, to compare the true necessity of locating a mine near its market both from a cost and environmental perspective. Despite the direct costs of freight travel alongside the consideration of various levels of generated externality costs, it appears cost effective to move the gravel mine up to over 1000 km away depending on the scenario. When considering the foregone positive benefits instead of property value losses, the difference between transportation costs and losses is even greater. These results counter the general perception in the gravel mining industry that it is beneficial for all parties to extract from deposits closer to urban areas first before moving further away.

In summary, there appears to be most notably positive impact on property values as a result of the positive environmental externalities generated from reclamation. The first model indicated a negative impact generated from extraction, however once time fixed effects were included the effect became insignificant. Although this result is sensitive, there are several limitations to the data used in this analysis that may have caused this. As the population of Alberta continues to grow at an increasing rate, so will our need for gravel to expand our cities. Counties and municipalities need to take special precautions where approving gravel operations to carefully include precautions for reclamation. Reclamation appears to be crucial to generate an upward swing in property value following extraction.

This research was somewhat limited by its data. There is only one year of observations available in the data set prior to the beginning of the gravel extraction, whereas there are 25 available post mine closure. This is a difference of approximately 400 observations versus 6500 observations. This data limitation may have generated bias in the results. There is another potential site that could be investigated in the Calgary area, but because the reclamation project only began in 2009 and there are no observations beyond 2010 I was unable to analyze the impact generated from that site. It would be interesting to analyze these impacts with a mine where there are more observations both before extraction and after decommissioning and subsequent reclamation.

Another interesting topic which could be examined would be the stigmatization impact mentioned by Messer et al (2006). Their results indicate that waiting longer to reclaim generates a stigmatization effect in a neighbourhood which causes property values to remain depressed even after reclamation has taken place. According to Erickcek (2009) this effect may exist as a result of gravel mining as well, but because this particular site was reclaimed rapidly, it did not make an ideal candidate to explore this phenomenon.

Finally, the results of this analysis are limited to an analysis of only one mine site. To truly understand the impact of gravel extraction on property values, a comparison across various gravel mines would be required. The impact that different mines would have on property values would depend on the size of mine, the length of time extraction occurs, the method of extraction, the mine's proximity to households and length of time once extraction ceases before reclamation takes place. This research only accounts for one scenario of multiple possibilities.

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Appendix

To test the robustness of the DD results, another model was run that this time interacted the DD parameter from the previous model with the inverse distance from the site. The results of this analysis, reported in Table 25, do not significantly differ from the previous DD model estimated. Again the DD parameter is positive and significant, providing evidence of the impact of the externalities generated by the mine on nearby property values. Including time fixed effects in this model does not significantly change the results, only the magnitude of some of coefficients including that of DD parameter change marginally.

Table 25 DD analysis results for Model 3 using a 2 km treatment area and indicating impacts of the gravel mine before and after the mine closed interacted with inverse distance from the site

	Model 3	
Attribute	OLS[1]	TFE[2]
Period 2: After	0.09915**	-0.15159***
	(0.0212)	(0.0389)
Treatment	0.03558	0.02154
	(0.0337)	(0.0315)
(Treatment	0.02226***	0.01946
*After)*Inverse Distance	(0.0340)	(0.0317)
Presence of Air	0.05541***	0.03306***
Conditioning	(0.0098)	(0.0095)
Waterfront	0.06837	0.11526***
	(0.0544)	(0.0343)
Presence of Basement	0.09933	0.04639
	(0.0661)	(0.0395)
Presence of Garage	0.01784	0.05618***
	(0.0127)	(0.0098)
Size of Garage	0.06491***	0.03709***
	(0.0081)	(0.0066)
Single Family House	0.1521***	0.18629***
	(0.0079)	(0.0062)
Deck or Balcony	0.05073***	0.02359***
	(0.0048)	(0.0039)
Area of Home	0.00229***	0.00188***
	(0.0004)	(0.0003)
Lot Size	0.0006	0.00009
	(0.0006)	(0.0001)
No. Bedrooms	0.01135***	0.00819***

	(0.0031)	(0.0026)
No. Bathrooms	0.08728***	0.06672***
	(0.0052)	(0.0043)
Fire Place	0.05948***	0.05903***
	(0.0058)	(0.0049)
Age of House	-0.00081***	-0.00310***
	(0.0003)	(0.0002)
Constant	11.80648***	11.92658***
	(0.03433)	(0.0446)
R^2	0.66	0.76
n	6941	6941

P<0.01=***, P<0.05=**, P<0.1=*

[1]OLS = Ordinary Least Squares

[2]TFE= Time Fixed Effects

In the single family homes case, Model 3 SFH, there is a similar impact in this model as in Model 2. The expected signs and significance are generated for all housing characteristics and the DD parameter. These values only change marginally with the inclusion of time fixed effects, and are reported in Table 26.

Table 26 DD analysis results for SFH in Model 3 using a 2 km treatment area and indicating impacts of the gravel mine before and after the mine closed interacted with inverse distance from the site

	Model 3 SFH	
Attribute	OLS[1]	TFE[2]
Period 2: After	0.06238**	-0.1626***
	(0.0116)	(0.0337)
Treatment	0.04518*	0.00812*
	(0.0056)	(0.0048)
(Treatment *After)*Inverse	0.04507***	0.03881***
Distance	(0.0032)	(0.0028)
Presence of Air	0.05440***	0.03307***
Conditioning	(0.0118)	(0.0101)
Waterfront	0.07609	0.116393**
	(0.0519)	(0.0443)
Presence of Basement	0.1101	0.04878
	(0.0944)	(0.0811)
Presence of Garage	0.02337***	0.05692***
	(0.0114)	(0.0098)
Size of Garage	0.06227***	0.03678***
	(0.0063)	(0.0055)
Deck or Balcony	0.04951***	0.02358***
	(0.0043)	(0.0037)
Area of Home	0.00229***	0.00188***
	(0.0001)	(0.0001)
Lot Size (m^2)	0.0000	0.0000
	(0.0000)	(0.0000)
No. Bedrooms	0.01160***	0.00827***
	(0.0028)	(0.0024)

No. Bathrooms	0.08666***	0.06675***
	(0.0040)	(0.0034)
Fire Place	0.05858***	0.05886***
	(0.0041)	0.0035)
Age of House	-0.00055***	-0.00304***
	(0.0001)	(0.0001)
Constant	11.8244***	11.9343***
	(0.0161)	(0.0335)
R^2	0.66	0.75
n	6361	6361

P<0.01=***, P<0.05=**, P<0.1=*

[1]OLS = Ordinary Least Squares

[2]TFE= Time Fixed Effects

The results change slightly in the condo segment of the market (Model 3 CONDO, Table 27). Again, some previously significant parameters such as the size of the garage and presence of a basement are no longer significant. The magnitude of the DD parameter is much smaller than for the single family homes; however it is still positive and significant. In all three cases then, there is an indication of the positive impact generated from completion of reclamation.

Table 27 DD analysis results for Condos inModel 3 using a 2 km treatment area and indicating impacts of the gravel mine before and after the mine closed interacted with inverse distance from the site

Model 3 CONDO

Attribute	OLS[1]	TFE[2]
Period 2: After	-0.09939***	-0.25896***
	(0.0296)	(0.0718)
Treatment	0.01098	0.06207**
	(0.0165)	(0.0136)
(Treatment *After)*Inverse	0.03122**	0.01714**
Distance	(0.0072)	(0.0058)
Presence of Air	0.02270	-0.00702
Conditioning	(0.0364)	(0.0292)
Waterfront	0.10937	0.07174
	(0.0944)	(0.0782)
Presence of Basement	N/A	N/A
Presence of Garage	0.32488***	0.20345***
	(0.0482)	(0.0391)
Size of Garage	0.0089124	0.05902**
	(0.0281)	(0.0227)
Deck or Balcony	0.04812***	0.01297
	(0.0149)	(0.0126)
Area of Home	0.00399***	0.00242***
	(0.0005)	(0.0004)
Lot Size (m^2)	0.0000	0.0000
	(0.0000)	(0.000)
No. Bedrooms	-0.03699***	0.0148751*
	(0.0117)	(0.0103)
No. Bathrooms	0.09424***	0.07356***

	(0.0179)	(0.0146)
Fire Place	0.06791***	0.08344***
	0.0160)	(0.0129)
Age of House	0.00799***	-0.00173*
	(0.0009)	(0.0010)
Constant	11.77344***	11.82487***
	(0.0667)	(0.0770)
R^2	0.73	0.84
n	580	580

P<0.01=***, P<0.05=**, P<0.1=*

[1]OLS = Ordinary Least Squares

[2]TFE= Time Fixed Effects