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Measuring the Impact of Coalbed Methane Wells on Property Values

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Abstract

By applying an hedonic model to a dataset of residential property sales and coalbed methane well locations in the Northern San Juan Basin, within La Plata County, Colorado, this analysis has shown that it is feasible to estimate an hedonic pricing model for residential properties within a defined portion of the Northern San Juan Basin. The model quantified many of the influences affecting selling price in the area, accounting for more than 86 percent of the variation in selling price of properties sold from 1989 through the first half of 2000. Independent of any changes in the nature of the housing stock, property values have risen rapidly in the study area from 1990 to 2000, reflecting appreciation of about 6.9 percent per year on average. The location of a well on a property at the time of sale had an impact on the property's selling price, other attributes being equal. Considering only properties sold with wells on them, there was an estimated net reduction in selling price of about 22 percent. This finding reflects the relatively large size and higher price of these properties, as well as other, offsetting proximity effects, including a positive effect attributable to the presence of wells within 550 feet but not on the property per se. The positive effect of nearby wells, a seemingly contradictory result, may have been due to a belief that the property would not be drilled because a well had already been drilled in close proximity— an effect that may not hold in the future. The impacts of coalbed methane wells, as measured across all properties sold in the study area and applied to an “average” property, is an estimated reduction in selling price of less than one percent. However, properties with wells on them account for most of the reduction in selling price. Overall, the findings of the study are consistent with results reported in the literature and with the experience of knowledgeable individuals interviewed locally. The value of this study is to empirically measure the level of overall impact to properties within the study area. On an individual basis, the exact character and features of one specific property versus another must be appraised to determine actual value.

Introduction

Oil and gas development, including development of coalbed methane (CBM), can entail many different relationships to nearby residential properties. Drilling activity may occur directly on a property, or it may occur in proximity to a property. At the completion of drilling, production activities and facilities on or near the property replace the activities and facilities of the drilling phase. Both the drilling and production phases of CBM development might involve noise, traffic, and types of activities of an industrial character. CBM development also may alter the landscape on, or visible to, nearby properties. On the other hand, specific features of terrain or vegetation may hide CBM activities from view or block out noise.

A number of La Plata County, Colorado residents believe that CBM activity has a negative effect on the value of nearby residential property. There is also an interest among surface owners for adjusting the value assigned to properties for tax purposes, according to County officials. Although the La Plata County Assessor currently does not adjust assessed values for the presence of wells, there is interest in doing so if there is a way to identify and determine the actual impact to market value (Kotlar 2000).

To examine this issue, BBC Research & Consulting (BBC) used multiple regression analysis to estimate an hedonic pricing model. The hedonic pricing model is a generally accepted technique for valuing factors that contribute to the price of a complex good like a residential property.¹ The model treats a property as a bundle of individual attributes, and estimates the portions of the sales price that willing buyers and sellers assign to each attribute. This allowed for an empirical test for the existence and magnitude of impact (if any) of CBM activity on the sales price of properties sold in the Northern San Juan Basin CBM project area.

The hedonic pricing model developed by this study estimates how the actual selling price of properties in the project area within La Plata County over the past decade may have reflected the impact of the proximity of CBM wells in place at the time of sale. Although such valuations are never explicit in the normal course of events, this approach applies econometric techniques to market and other data to isolate the implicit, marginal price impact of wells in varying locations with respect to the selling property.

Note that the value of this study is to empirically measure the level of *overall impact* to properties within the study area. Estimates of impact to individual properties will vary from case to case, depending on specific location and the exact character and features of a property, including factors that may not be explicit in the model.

Coalbed Methane in La Plata County

The Fruitland coalbeds of the San Juan Basin are at the surface in the northern part of the Basin just south of the City of Durango in La Plata County. The coal is thick and of good quality, but it tilts steeply southward so it is virtually impossible to mine. However, the same coal is also a major reservoir of natural gas in the form of CBM (Blair 1996).

Development of CBM was modest in the San Juan Basin until the mid-1980s after passage of the Crude Oil Windfall Profits Tax Act of 1980. The act, which was extended through 1992 and included subsidies for operations that are due to expire in 2002, was the key incentive for operators to overcome the technical problems of extraction (Bureau of Land Management 2000).

San Juan Basin CBM development rapidly increased during the 1990's. The area from just south of the City of Durango to the Navajo Reservoir extending into New Mexico has been the largest producing CBM area in the world (Blair 1996) and the long-term trend suggests that coalbed gas will outpace development of new wells in the Basin's conventional sandstone formations (Bureau of Land

¹ This method of analysis is the standard for "supportable, defensible market impact studies" (Kinnard and Dickey 1995, p. 23).

Management 2000). Operators also are pursuing CBM development with increasing intensity in the area east of the City of Durango in southeastern La Plata County (Bureau of Land Management 2000).

Perceptions of CBM Effects to Property Values

Much of the CBM development occurring in the Northern San Juan Basin has been on the Southern Ute Indian Reservation in the southeast corner of La Plata County. However, the area outside the reservation, running along and north of U.S. 160 from just southeast of the City of Durango to the Archuleta county line, is also the focus of renewed CBM development, as well as being the target for development of low- and medium-density, rural residential subdivisions. As details of CBM's possible future path have emerged, concerns have arisen about the potential for impacts to property values in this sub-area as in other parts of the northern Basin.

Following the example of Michaels and Smith (1990), BBC completed background research on the local context, including a number of interviews with a variety of knowledgeable individuals. The research sought to improve understanding of perceived influences on housing values in the study area, identify important perceptions of the relationship between CBM development and residential land use, and qualitatively describe the housing stock within the study area. BBC considered observations made during this reconnaissance in constructing the model to identify and measure any potential impacts.

In particular, real estate agents specializing in the sale of properties within the area affected by CBM development were interviewed to qualitatively describe the housing stock within the study area in terms of characteristics that influence value and perceptions of CBM activity's impact on sales (Allen 2001, Campbell and Royer 2001, Fryback and Lorenz 2001, Jefferies 2001, Kurlander 2001a, Piccoli 2001, Zartner 2001a). These interviewees identified a number of specific characteristics that may tend to affect property values: acreage, views, vegetation, water features, rural "feel," accessibility to the City of Durango, schools, topography, privacy, covenants and the density, quality and character of surrounding development. The real estate agents also agreed that property values tend to increase, on average, as the distance to the City of Durango decreases. Consistently throughout these interviews, respondents observed that surface property owners perceive CBM activity as having an adverse, if localized, effect on property values within view or earshot of CBM facilities.

Interviewees said that surface owners generally identify impacts associated with what they believe to be CBM activity's direct effects and potential risks. Perceived direct effects include changes to views, noise, traffic, and—indirectly because of traffic—airborne dust and road damage. According to the interviewees, the risks that surface owners perceive may include groundwater contamination, methane gas seeps, and coal fires.

Real estate agents interviewed confirmed the perception of impacts to property values from CBM activity. Some said they believe that a well may impact a property if the well's effects, such as visibility and noise, impinge upon the property, regardless of whether the well is actually located on the property or not. However, interviewees said they believe a property is most affected in the event that a well is located directly on it, although the intensity of effect may vary with the size of the property and the opportunities available to maintain separation between the well and the residence or other improvements. Several interviewees said they believe they have seen both specific cases and

general market evidence of CBM impacts to values including effects to the value of vacant and agricultural land. Some cited cases where they observed different prices for specific pairs of seemingly comparable properties sold within a relatively short time span.

Some interviewees noted other localized aspects of CBM activity's perceived effects on the real estate market. The so-called "gas zone" is an identifiable sub-area of the County and, according to the realtors, buyers and the agents who represent buyers and sellers, may tend to avoid this area. As perceived by the real estate agents, this pattern of behavior may tend to reduce demand for gas zone properties.

Background on Hedonic Pricing Analysis

Given the consensus among these individuals, this study tested the hypothesis that CBM development activity has an effect on surface property values. An extensive literature review in the disciplines of economics, land use and real estate identified numerous studies since the early 1970s that have investigated the effect on property values of proximity to special, distinguishable features and activities. These special features, near but not part of the real estate to be valued, are referred to as "externalities." These have included both positive and negative attributes, from beaches to power lines to hog farms. Most studies of externalities have used a valuation technique called hedonic pricing.

The literature on hedonic pricing of residential real estate falls into two general categories. The first—the theoretical literature—focuses on identification of housing supply and demand equations and comparisons among equations of differing forms. The second category is the empirical literature. The empirical papers describe particular, hedonic pricing investigations where the measurements of interest are the implicit prices of structural and physical characteristics of properties, plus at least one additional characteristic drawn from the surroundings, such as the community, the neighborhood or an external amenity or disamenity.

Before one can evaluate the impact of an external characteristic, effects must be controlled for other factors of importance. For example Palmquist, Roka and Vukina 1997 controlled for the characteristics that are expected to contribute to a home's sale price in order to properly estimate the effect of the proximity of a hog farm.

There is a consensus among economists as to the general factors that explain the market price of a property. Pompe and Rinehart (1995) investigated the impact of beach quality on the purchase price of single-family homes with and without water frontage in South Carolina. The authors used a standard hedonic pricing model,

$$P_i = f(s_i, n_i, x_i).$$

where P is the selling price of a property. The expression includes structural characteristics (s), neighborhood characteristics (n), and external effects (x). The structural characteristics were age of house, size of living area, number of bathrooms, and having a fireplace. The neighborhood characteristics were distance to Myrtle Beach and whether the property sold after Hurricane Hugo in 1989. To measure the externality of interest, beach quality from the perspective of the property, the

model included both width of the nearest beach at high tide and distance to the nearest beach multiplied by the width of the nearest beach at high tide. The model also controlled for a property's ocean views, being on the water, and having a dock, all attributes expected to impact property values.

The hedonic pricing model developed by Pompe and Rinehart is similar to that used across the economics and planning literature. For other representative examples, see Palmquist, Roka and Vukina (1997); Palmquist (1992); Graves et al. (1988); Ridker and Henning (1967) and Levesque (1994). Levesque 1994 specifies the following form for the pricing model, which incorporates the effect of time:

$$P = f(z_1, z_2, \dots, z_m, a_1, a_2, \dots, a_m, t).$$

In this expression:

- P is the market price of a house;
- The z 's are continuous variables like the duration or intensity of a disamenity (e.g., distance to a waste site, frequency or level of noise events, etc.) or a housing characteristic (e.g., square footage, lot size, distance to town, etc.);
- The a 's are a series of specific attributes that either do or do not exist (e.g., on the waterfront, has a garage, etc.); and
- The t is the period when the property sold.

Most studies apply log-likelihood ratio tests to select the best among competing models. Four functional forms are typically tested: linear, semi-logarithmic, log-linear, and exponential (Palmquist 1984; Levesque 1994; Dickie et al. 1997).

BBC reviewed 12 studies that included empirical estimations of implicit prices to arrive at guidelines for this study. The structural characteristics incorporated in these models may include: age of house, size of living area, size of lot, number of bathrooms, existence of a porch or deck, existence of a fireplace, type of heating, type or size of garage, hardwood floors, landscaping, house construction, and date of sale. Similarly, there was consistency in the use of location effects. These tended to include some measure of commuting time or accessibility, and one or more neighborhood or community effects (e.g., socioeconomics, public safety, recreation, etc.). The studies considered a range of externalities, among them distance to the beach, existence of a nice view, highway noise, distance to a noxious site (e.g., a landfill), and airport noise.

Hedonic studies are complex and have limitations. Many factors may contribute to the perceived value of any individual property. Not all of these factors can be measured. No model can "explain" 100 percent of the variation in the sale price of a home. The portion of the variation that is unexplained in hedonic pricing models of housing values ranges in the literature from 19 percent (Pompe and Rinehart 1995) to 10 percent (Palmquist 1992).

In addition, housing markets vary substantially from place to place. Because of this, analysts generally do not transfer estimated magnitudes of a variable measured in one market to other markets not considered in a study. For example, the square footage of a house is statistically significant in explaining valuation differences in every model identified by the study team. While specific

quantitative measurements of the effect of square footage on the total sales price cannot be generalized from one geographic area to another, it is reasonable to expect that square footage will be significant in future studies and should be included in the analysis.

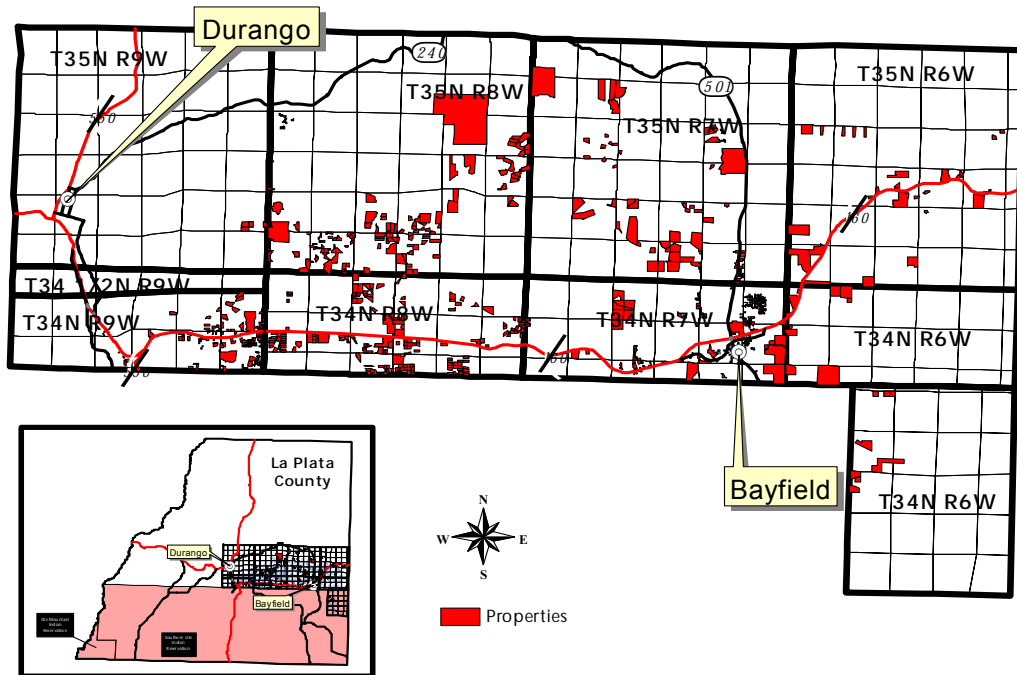
Despite limitations, hedonic analysis provides an established and practicable basis for the pricing of specific property characteristics in a complex housing market like La Plata County for a number of reasons. The method relies upon actual market data. Such models can also incorporate techniques to explicitly measure appreciation over time from these data instead of relying on external measures of inflation. The large body of empirical studies provides benchmarks for the evaluation of new studies. Finally, hedonic analysis is a practical approach in most housing markets because adequate, usable data is often generally available. Competing methods include contingent valuation and discrete choice modeling. Each of these alternatives involves surveying numerous individuals in experimental settings that attempt to simulate the relevant market and would have measured intended rather than actual behavior. In addition, competing methods tend to focus on situations involving a few instead of many attributes.

Data for the Analysis

The property data used in this analysis was purchased by special arrangement from Allen & Associates, a Durango real estate appraisal and information services firm. Allen & Associates prepares its database from public information available to the County Assessor at the time of sale. The database includes many property characteristics: parcel number, sale date, sale price, lot size, type of use (vacant, residential, mobile home, etc.), year of construction for primary improvement, square footages by floor level, total improved square footage, number of baths, number of bedrooms, type of heat, garage type and square footage, and more. Some data elements (including bedrooms, bathrooms and heat) were incomplete for many properties and, consequently, the analysis excludes them.

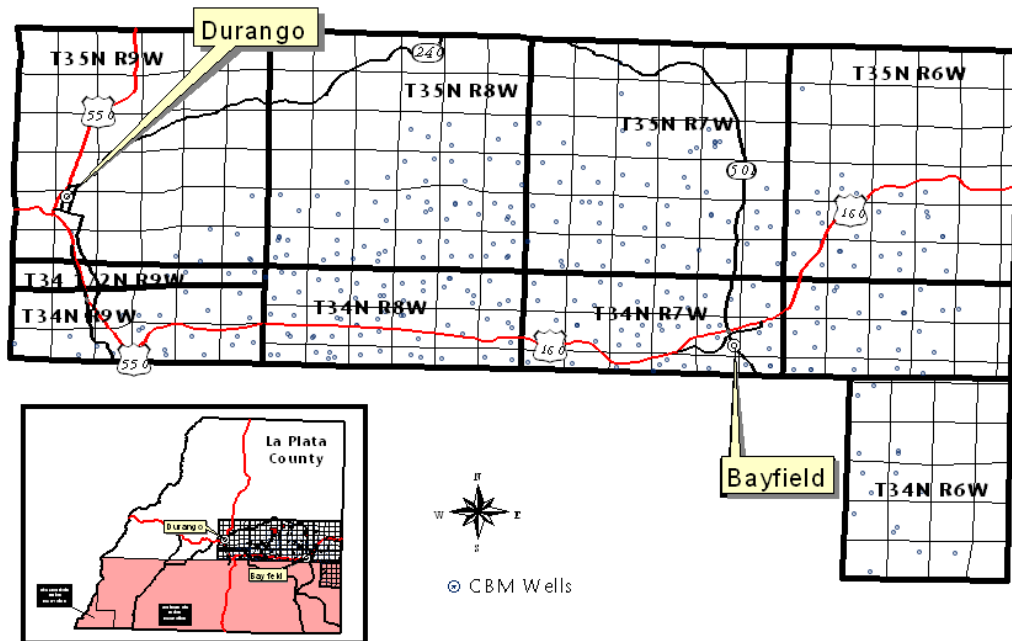
The properties selected for this analysis were located within the study area and sold in the period from 1989 through the first half of 2000. (See Attachment A for the definition of the study area included in the dataset.) The analysis includes all 754 properties identified for modeling purposes. Figure 1 illustrates the properties included in the analysis. The distance from the center of each parcel to the center of the City of Durango was calculated using geographic information systems (GIS) software procedures, and was added to each record in the dataset.

Figure 1.
 Properties Sold in the Study Area from 1989 through the First Half of 2000



BBC compiled data on CBM wells within the study area from the online database of the Colorado Oil and Gas Conservation Commission. Key data items for each well are the well location and completion date. There are 326 CBM wells, existing or completed during this period, that were included in the study. Conventional wells were not included. Figure 2 illustrates the CBM wells included in the analyses.

Figure 2.
Cumulative CBM Wells in the Study Area from 1989 through the First Half of 2000



Again using GIS software, BBC created new variables to indicate the presence of an active well on or near a property at the time of sale and added these items to the property sales dataset. Proximity to a well from the center of a parcel was used as the proxy to measure the possible effects of visibility, noise, traffic, and safety concerns related to CBM activity proximate to a property. Note that this analysis omits other CBM facilities that may well have an effect on property values, too (e.g. compressor stations).

Analysis Framework

The BBC model used in the analysis follows the standard framework found in the literature, with some modification to reflect this specific analysis and the results of the regional interviews:

$$P = bS + cW + dT + b'TS + u$$

The *S*-term in this expression represents an array of general characteristics of the structure and the property. After exploring the measures available in the purchased dataset, a number of variables were selected based on past studies. These include total square footage of the house, property acreage, age of the house, whether the property has a garage, whether the residence is a mobile home, and the distance to the City of Durango (measured from the center of a property to the center of the City of Durango, as reflected in GIS maps collected from La Plata County). Additional acreage, square footage and the presence of a garage were expected to positively influence property values. No information was available, going in, to strongly indicate an expected direction of influence for the age of a residence or its being a mobile or manufactured home instead of a site-built structure.

Consistent with other hedonic property value studies, variables were included for both the acreage of the property and the square of the acreage of the property. This allows for the possibility that per-acre land values for developed properties may not always have a linear relationship to the size of the property. That is, the land value of a 100-acre parcel may not be 400 times the land value of a quarter-acre parcel.

The S -term also includes the measure of distance from the property to the City of Durango. Based on BBC's interviews of real estate agents, distance from a property to the City of Durango was expected to have a negative influence on selling price. That is, as distance to the City of Durango increases, the impact on selling price would increase and the total selling price would decrease, all else being held constant.

The model controls for the year a property sold (T), and, through the term TS , it allows for the impact of the general and structural characteristics (e.g., square footage) to vary with time. The interaction variables are calculated by multiplying each variable (e.g., acreage) times the number of years after 1989—the beginning of the study period—that the property was sold. The value of T ranges from zero for 1989 to 11 for 2000.

The W -term represents the four measures of the proximity of a property to CBM wells in existence at the time of sale. The measures are:

- One or more wells are on the property (a binary, or “dummy,” variable that takes on a value of either “0” or “1”);
- Number of wells within 550 feet of the property's center, excluding any wells on the property;
- Number of wells from 551 to 1,100 feet of the property's center; and
- Number of wells from 1,101 to 2,600 feet of the property's center.

The u -term is an element of regression models that accounts for random error unexplainable by any other means.

The study tested the hypothesis that an active CBM well on a property at time of sale would negatively affect a property's sale price. The impact on selling price of wells at a distance from properties might also be negative, but at a declining level as distance increases. This would reflect the diminishing effect of specific well impacts (visibility, noise, perceptions of risk, etc.) and the increasing opportunity for separation and screening as distance increases.

Results

BBC performed a multiple regression analysis on the dataset of 754 property sales in the study area from 1989 through 2000. The base version of the model, which excluded measures of CBM well proximity, was able to account for more than 85 percent of the variation in property sales prices over the study period. This value is within the range of performance (81 percent to 90 percent) for hedonic pricing models of residential real estate as seen in the literature described earlier.

Fifteen of the 23 structural and locational variables considered, including time interaction variables, were statistically significant in the base model at the 99 percent confidence level. Three other variables are significant at confidence levels of 95 percent or 90 percent. Five variables were not statistically significant, but were included in the final model because of their sound theoretical basis—even though it is statistically possible that the effect of these variables is really zero despite the appearance of non-zero coefficient values produced by the analytical procedure. These coefficients do vary in the direction one would expect, i.e., property values are less if the dwelling is a mobile home, or if the dwelling is older. The dataset did not consistently report the number of bathrooms and number of bedrooms, so the analysis omits these items.

As a next step, BBC expanded the model to include the four measures of proximity of properties to CBM wells at time of sale. Based on their inclusion, the final dataset contained 12 properties sold between 1989 and 2000 that had a CBM well located on the property at time of sale and 544 properties with a well located off the property but within 2,600 feet of the center of the property at time of sale. Table 1 presents the summary statistics for the resulting dataset (N = 754) and for two sub-samples consisting of properties sold with a well on them (N = 12) and properties sold with a well near but not on the property (N = 544).

*Table 1.
Descriptive Statistics of the Dataset of Property Sales in Study Area*

<i>Attributes of Properties Analyzed</i>	<i>All Sales N=754 Mean</i>	<i>Sold With Well On Property N=12 Mean</i>	<i>Sold With Well Near But Not On Property N=544 Mean</i>
Average Miles From The City of Durango	11.22	7.61	11.46
Average Acreage	6.95	39.33	6.40
Average Acreage Squared	327.04	2,865.55	244.18
Average House Square Footage	1,458.79	1,668.58	1,454.67
Average House Age	20.05	20.92	20.48
Percent of Cases with Garage	53%	42%	55%
Percent of Cases Where Residence is a Mobile Home	9%	17%	9%
Percent of Cases with 1 or More Wells On Property	2%	100%	-
Average Number of Wells within 550 feet but Not on Property	0.02	0.58	0.01
Average Number of Wells within 551 to 1,100 feet	0.14	0.50	0.18
Average Number of Wells within 1,100 to 2,600 feet	1.01	0.50	1.38

Figure 3 is a supplement to Table 1 that shows the distribution of transactions by year sold.

*Figure 3.
Distribution of All Sales in Dataset by Year Sold*

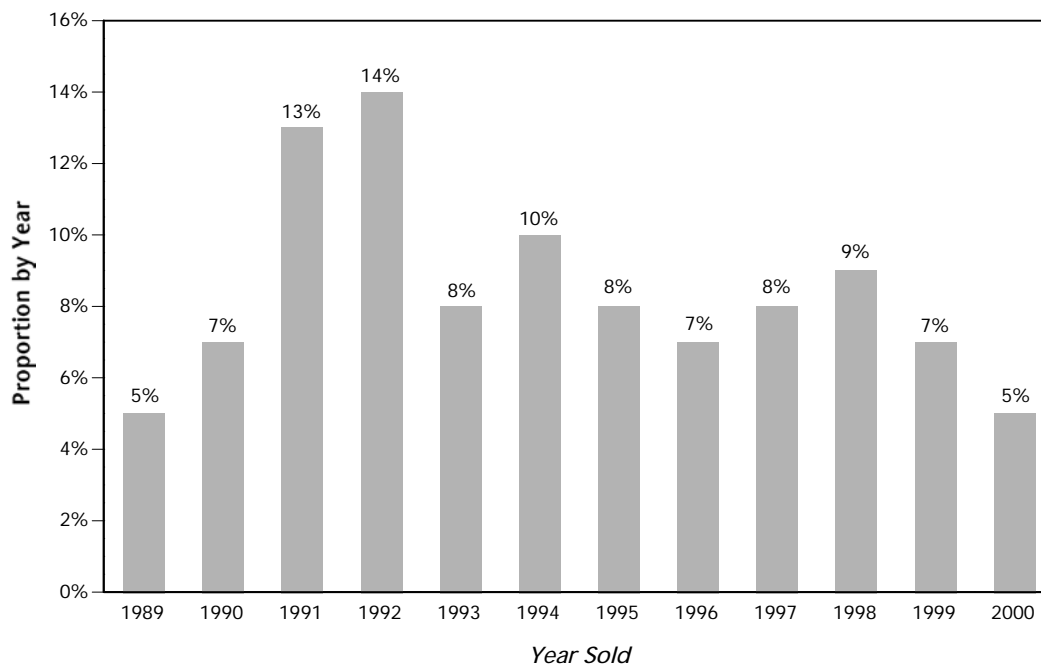


Figure 3 presents the values of the year-of-sale, “dummy” variables that are coded as a “1” for properties sold in a given year and a “0” for properties sold in all other years. The mean value of these variables is equal to the proportion of the properties in the whole dataset sold in each year.

Note that, as indicated by Table 1, only 12 properties in the dataset had a well on them when sold. The small number of properties sold with wells on them does not diminish the validity of the model. The addition of the properties with wells to the base model strengthens the overall results, and the inclusion of wells improves the model’s ability to explain variation, as reflected in the R-squared statistics.²

Table 1 also indicates that properties sold with a well on the property differed in several characteristics from the average property characteristics in the dataset as a whole, and from the average characteristics of properties sold with a well nearby but not on them:

- Properties sold with a well on them had an average size of about 39 acres compared to an average of about seven acres for the dataset as a whole.
- The house size for properties with wells on them averaged about 1,670 square feet compared to an average of about 1,460 square feet for the dataset as a whole.

² R-squared, which varies in value from 0 to 1, expresses how closely the regression model fits the data. R-squared (also called the “coefficient of determination”) is the proportion of the total variation in the dependent variable (in this case, selling price) that is “explained” by the regression model. An R-squared of 0.86 means that using the regression model, with all the relevant attributes included, to estimate each selling price explains, or eliminates, 86% of the total error that would otherwise be made by simply assuming each selling price to be equal to the overall average selling price.

This impact estimate is highly reliable from a statistical standpoint, despite its basis on a small number of sales with wells on the property. The model as a whole considered 754 cases, and its performance, as measured by R-squared, improved with the inclusion of the with-well-on-property sales. Note also that the impact cited here measures the overall average for the 12 cases considered. Impacts to specific properties depend on location, terrain and other characteristics on a case-by-case basis.

Table 2 presents the estimates for all model coefficients and their significance relative to confidence levels of 99 percent and 95 percent. These estimates include the effects of CBM wells.

Table 2.
Impacts of Each Year and Each Property Attribute on Model Results

<i>Property Attributes</i>	<i>Coefficient</i>	<i>Statistical Significance</i>
Overall Model R-squared	0.860	
<u><i>Impact of Year of Sale (Relative to 1989 sales)¹</i></u>		
Sold in 1990	\$44,244 per property	***
Sold in 1991	\$33,224 per property	***
Sold in 1992	\$40,517 per property	***
Sold in 1993	\$43,140 per property	***
Sold in 1994	\$36,023 per property	***
Sold in 1995	\$58,355 per property	***
Sold in 1996	\$79,804 per property	***
Sold in 1997	\$48,831 per property	***
Sold in 1998	\$51,815 per property	***
Sold in 1999	\$46,361 per property	**
Sold in 2000	\$50,638 per property	**
<u><i>Impact of Structure and Location</i></u>		
Miles from The City of Durango	-\$2,469 per mile	***
Acreage	\$398 per acre	
Acreage x T	\$471 per acre, times years since 1989	***
Acreage Squared	\$17.6 per acre squared	***
Acreage Squared x T	-\$3.8 per acre squared, times years since 1989	***
House Square Feet	\$27.1 per square foot	***
House Square Feet x T	\$4.2 per square foot, times years since 1989	***
Property Has Garage	\$23,173 per property	**
Garage x T	\$914 per property, times years since 1989	*
House Age	\$245 per year	*
House Age x T	-\$23.8 per year, times years since 1989	*
Residence is a Mobile Home	-\$9,356 per property	*
Is a Mobile Home x T	-\$4,925 per property, times years since 1989	*
<u><i>Impact of Well Proximity</i></u>		
1 or More Wells on Property	-\$103,169 per property	***
Number of Wells Within 550 Feet	\$64,435 per well	***
Number of Wells Within 552 to 1,100 Feet	-\$4,550 per well	*
Number of Wells 1,101 to 2,600 Feet	-\$51 per well	*

*Statistically different at less than 95 percent confidence level.

**Statistically different at 95 percent confidence level.

***Statistically different at 99 percent confidence level.

¹Appreciation in the property market was captured through both a constant variable for all properties in each year (e.g., "Sold in 1991," etc.) and through interaction terms measuring changes in the value of property characteristics over time (e.g., "Acreage x T").

As measured by its R-squared, the model that includes CBM wells accounts for 86 percent of the variation in property sales prices over the timeframe of the study. The hedonic pricing model of property values yielded the following results:

- Fifteen of the 23 structural and location variables included in the model are statistically significant at the 99 percent confidence level. This includes both the variables portraying property attributes and the variables representing their interactions with time.
- Three other variables are significant at the 95 percent confidence level.
- The coefficient of the variable indicating whether there was a well on the property at the time of sale is numerically large, negatively correlated to property value and statistically significant at the 99 percent level.
- The coefficient of the variable counting the number of wells off the property but within 550 feet of the center of the property is large, positive and statistically significant at the 99 percent level.
- Two of the four proximity variables in the final model (for number of wells at distances of 551 feet to 1,100 feet and at distances of 1,101 feet to 2,600 feet) are estimated to have small coefficients that are not statistically significant.

The values estimated from the available data were found to contradict the expectation that property values would decline in the nearest distance zone (within 550 feet but not on the property). BBC pursued additional information on the effect by re-interviewing three of the real estate agents (Kurlander 2001b, Lorenz 2001, Zartner 2001b). The real estate agents suggested that there might indeed be a reasonable basis for this effect to be positive. The impact of a well within 550 feet of a property may be positive, if one takes into account the spacing order that prevailed at the time,³ plus the setback requirements of the Colorado Oil and Gas Conservation Commission (Colorado Oil and Gas Commission Rule 603). Under those conditions, the marketplace may have perceived the well's presence as a signal that no further development would occur in that proximity, assuming no change in the spacing order.

Given the estimates presented in Table 2, BBC conducted further analysis, using the model with CBM wells, to generalize about the residential real estate market's behavior and about the relative scale of impacts to residential property values that may have occurred during the study's timeframe. Table 3 presents the first of these applications: a calculation of estimated effects of each variable on home values in the year 2000. In this application, the model is applied to a hypothetical property with the average characteristics of the entire sample.

³ Colorado Oil and Gas Commission Order No. 112-60, June 15, 1988, established 320-acre drilling and spacing units for Fruitland gas wells in the Ignacio-Blanco Field. The units consist of a government half section. Wells are to be located in the NW $\frac{1}{4}$ and SE $\frac{1}{4}$ of each section, no closer than 990 feet to the quarter section boundaries and no closer than 130 feet to any interior quarter section line.

*Table 3.
Estimated Value of Residential Property and Attributes in Year 2000*

<i>Property Attributes</i>	<i>2000</i>
Constant for Year 2000	\$50,638
<i><u>Impact of Property Characteristics</u></i>	
Miles from The City of Durango	-\$27,702
Acreage (Acreage + Acreage Squared)	\$30,877
House Square Feet	\$106,929
Garage	\$17,610
House Age	-\$337
Mobile Home	-\$5,476
<i>Total Property Value: Excluding Well Effects</i>	<i>\$172,539</i>
<i><u>Impact of Well Proximity</u></i>	
If 1 or More Wells on Property	-\$1,642
Number of Wells Within 550 Feet	\$1,106
Number of Wells Within 551 to 1,100 Feet	-\$627
Number of Wells 1,101 to 2,600 Feet	-\$51
<i>Total Property Value: Including Well Effects</i>	<i>\$171,325</i>

Note: Values for acreage, house square feet, garage, house age, and mobile home are combined totals of the variable's main effect and its interaction with time. The value for acreage is the sum of the main and interaction effects of both nominal acreage and acreage squared.

By combining the effects of the characteristics variables and their time interactions, one can estimate the contribution of various attributes to the \$171,300 value of the “average” property in the dataset in the year 2000. These contributions are about \$30,900 for the acreage, \$106,900 for residential square footage, \$17,600 for garage value, and \$15,900 for the net of all other characteristics. Based on the “average” property profile for all transactions studied, the total impact of well proximity in the year 2000 was an average reduction in value of about \$1,200. Note that estimates of impact vary from case to case, depending on specific location and individual characteristics, including factors that may not be explicit in the model.

BBC also used the model to estimate appreciation in property values. The value of a home with the average characteristics of all property sales in the dataset would have increased from about \$87,500 in 1990 to about \$171,300 in 2000.⁴ This indicates property value appreciation of 6.9 percent per year for the past decade in this market area. Figure 4 illustrates this effect.

⁴ See Table 1 for the average characteristics of all 754 properties in the sales dataset.

Figure 4.
Average Property Value, Including Well Effects: 1990 to 2000

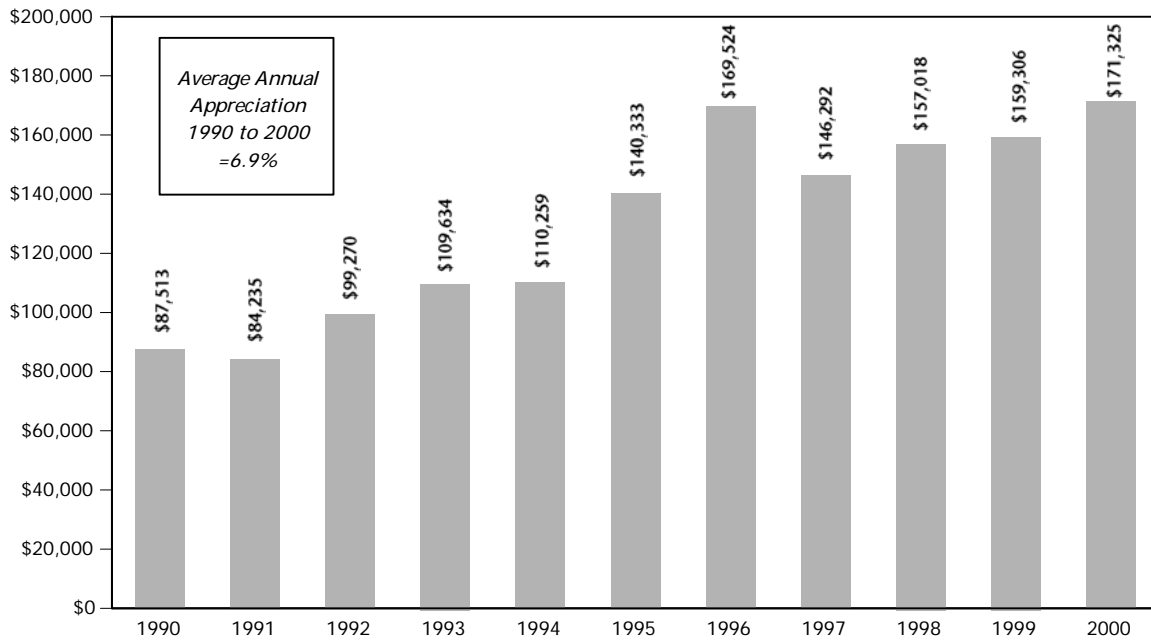


Table 4 presents a second application: the calculation of estimated effects of the well proximity attributes on values for homes that specifically have a well located on their property versus properties that do not.

Table 4.
 Estimated Value of Residential Property in 2000, Well on Property versus No Well on Property

<i>Property Attributes</i>	<i>Sales With Well On Property N=12</i>	<i>Sales With Well Near But Not On Property N=544</i>
Constant for Year 2000	\$50,638	\$50,638
<i><u>Impact of Property Characteristics</u></i>		
Miles from The City of Durango	-\$18,786	-\$28,295
Acreage	\$15,651	\$2,547
Acreage x T	<u>\$203,743</u>	<u>\$33,153</u>
Total Acreage Value	\$219,394	\$35,700
Acreage Squared	\$50,434	\$4,298
Acreage Squared x T	<u>-\$119,780</u>	<u>-\$10,207</u>
Total Acreage Squared Value	-\$69,346	-\$5,909
Acreage (Acreage + Acreage Squared)	\$150,048	\$29,791
House Square Feet	\$45,219	\$39,422
House Square Feet x T	<u>\$77,088</u>	<u>\$67,206</u>
Total House Square Feet	\$122,307	\$106,628
Has Garage	\$9,733	\$12,745
Garage x T	<u>\$4,223</u>	<u>\$5,530</u>
Total Garage	\$13,956	\$18,275
House Age	\$5,125	\$5,018
House Age x T	<u>-\$5,477</u>	<u>\$5,362</u>
Total House Age	-\$352	-\$344
Residence is a Mobile Home	-\$1,591	-\$825
Is a Mobile Home x T	<u>-\$9,210</u>	<u>-\$4,778</u>
Total Mobile Home	-\$10,801	-\$5,603
<i>Total Property Value: Excluding Well Effect</i>	<u><i>\$307,010</i></u>	<u><i>\$171,090</i></u>
<i><u>Impact of Well Proximity</u></i>		
1 or More Wells on Property	-\$103,169	-
Number of Wells Within 550 Feet	\$37,372	\$709
Number of Wells Within 551 to 1,100 Feet	-\$2,275	-\$819
Number of Wells 1,101 to 2,600 Feet	-\$26	-\$71
<i>Total Property Value: Including Well Effect</i>	<u><i>\$238,912</i></u>	<u><i>\$170,909</i></u>
% Impact of Well Effects	<u><i>-22%</i></u>	<u><i>0%</i></u>

Note: Values for acreage, house square feet, garage, house age, and mobile home are combined totals of the variable's main effect and its interaction with time. The value for acreage is the sum of the main and interaction effects of both nominal acreage and acreage squared.

For each of the columns in Table 4, the calculations are based on properties sold in year 2000 and the average values of the characteristics of all properties in the dataset.

Table 4 leads to the following observations:

- The subgroup of properties with wells on them had a higher than average estimated property value, excluding well proximity effects, of about \$307,000. This is because of larger acreages and home sizes in the subgroup, compared with the dataset as a whole.
- Within the subgroup of properties with wells on them, the net impact of all well effects is estimated to be a reduction in value of about \$68,100, or about 22 percent. Note that the relatively large size and higher price of these properties affects the level of impact estimated for the group overall.
- Properties that had wells located nearby, but not on the property, generally followed the pattern of positive price effects of wells within 550 feet and negative effects of more distant wells.
- Within the subgroup of properties with wells near but not on them, the roughly \$200 net reduction in value attributable to well proximity effects equates to a very small average impact that is close to zero. The low impact is due to the offsetting effect of wells within 550 feet in this subgroup, which are thought to have signaled protection from eventually having a well located on the property under previous spacing orders.
- Off-property wells located further from the center of the property had a modest negative impact on value, although the existence of this effect is uncertain, given that the coefficient estimates for these more distant impacts are not statistically significant at a very high level of confidence.

Conclusions

Hedonic pricing models may provide a practical and reliable way to price the specific characteristics of properties in a complex housing market, including external characteristics like the presence of gas wells on or near the property. The use of multiple regression analysis in the hedonic pricing model format has numerous precedents. In this case study, it also has shown the ability to produce a statistically significant result using readily available data.

By applying hedonic property value analysis to a dataset of residential property sales and CBM well locations in the Northern San Juan Basin, this analysis has produced these findings.

- It is feasible to estimate a hedonic pricing model for residential properties within a defined portion of the Northern San Juan Basin, and the model can quantify many of the influences affecting property values in the area.
- The model was able to account for more than 86 percent of the variation in the selling price of properties transacted over the period from 1989 to 2000.
- Independent of any changes in the nature of the housing stock, property values have risen rapidly in the study area. A property with the average attributes of all properties in

the dataset as a whole would have sold for about \$87,500 in 1990 and about \$171,300 in 2000, reflecting average annual appreciation of about 6.9 percent. Much of this appreciation occurred through 1996; as indicated in Figure 4, appreciation growth has flattened out recently.

- The location of a well on a property at the time of sale had an impact on the property's selling price, other attributes being equal. The model estimates the impact on properties with wells on them to have been a net reduction in value of about \$68,100, or 22 percent.
- The net impact to the sales price of properties sold with wells on them includes other, offsetting proximity effects. The net effect of well proximity effects on the average value of properties sold with a well on them also included the offsetting positive effect attributable to wells within 550 feet. The positive effect of nearby wells, a seemingly contradictory result, is most likely attributable to a belief that the property in question would not be drilled because a well had already been drilled in close proximity. It is unpredictable whether this effect will hold in the future, given changes in well spacing orders for the Study Area.
- Wells located farther from the center of properties sold within the study area—at distances of greater than 550 feet and up to 2,600 feet—had a modest impact, if any, on the value of the property.
- The overall impacts of CBM activity—measured across all properties sold in the study area as reflected in Table 3 and applied to the average acreage of all properties reflected in Table 1—are an estimated reduction in property value of \$175 per acre during the time studied, or less than one percent on average. As described above, those properties with wells on them account for most of the diminished property value.

The findings proved to be consistent both with results reported in the literature and with the experience of knowledgeable individuals in the local community.

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Attachment A

Sections in Study Area North of Southern Ute Indian Reservation Line

<i>Township</i>	<i>Range</i>	<i>Sections</i>
T 34 N	R 6 W	1 – 18
	R 7 W	1 – 18
	R 8 W	1 – 18
	R 9 W	1 - 3, 4 (p), 5 (p), 7 (p), 8 – 12
<i>T 34 ½ N</i>	<i>R 9 W</i>	<i>33 (p), 34 – 36</i>
T 35 N	R 6 W	13 (p), 14 (p), 15 (p), 16 (p), 17 (p), 18 (p), 19 - 23, 24 (p), 25 (p), 26 - 35, 36 (p)
	R 7 W	7 (p), 8 (p), 9 (p), 13 (p), 14 (p), 15 (p), 16 - 36
	R 8 W	10 (p), 11 (p), 12 (p), 13, 14, 15 (p), 16 (p), 17 (p), 18 (p), 19 (p), 20 - 36
	R 9 W	24 (p), 25, 26 (p), 34 (p), 35, 36

Study Area Below Ute Line

<i>Township</i>	<i>Range</i>	<i>Sections</i>
T 34 N	R 6 W	3U, 4U, 5U, 6U, 7U, 8U, 9U, 10U, 15U, 16U, 17U, 18U, 19 - 22, 27 - 34

(p) indicates the section is only partially within the study area.

La Plata County has two T 34N's. A "U" is attached to Sections 1 through 18 in T 34N south of the Ute Line to distinguish them from the same section numbers in T 34N north of the Ute Line.