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Natural Gas Pipelines and the Value of Nearby Homes: A Spatial Analysis

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Abstract

We examine the effect of a natural gas pipeline on the sales prices of nearby homes in Hillsborough County, Florida. We use an ordinary least squares regression model in the hedonic format to regress the natural logarithm of sale price on a vector of housing, neighborhood, transactional, and environmental characteristics. We apply spatial autocorrelation using two spatially autoregressive modeling techniques: the spatial lag model and the spatial error model. The results yield statistically insignificant coefficients for each distance band, which indicates that it is highly unlikely that there is an association between the sale price of a home and its proximity to a natural gas pipeline.

There are over 2.6 million miles of pipelines crossing the United States carrying hazardous liquids, gasoline, and natural gas. The construction of pipelines and the condemnation of land for pipelines has been ongoing at a torrid pace, with 21,412 miles of pipelines in the engineering and design phase and 12,615 miles under construction in 2016.[1] The amount of land needed for pipeline right-of-way is not expected to slow anytime soon, with a projected need for an additional 22,500 miles of pipeline right-of-way for natural gas alone.

According to U.S. Department of Transportation data, pipelines are the safest and most cost-effective means to transport large volumes of natural gas, and based on comparable volumes of gas and oil transported, pipelines are extremely safe compared with other modes of energy transportation.[2] However, pipelines are not without risk, potentially even catastrophic risk. On average, there have been 637 pipeline incidents, 15 fatalities, and $470 million dollars of property damage each year for the last 10 years.

At 6:10 pm on September 9, 2010 in San Bruno, California, a 30-inch diameter natural gas pipeline exploded killing eight people. The explosion ignited a fire that lasted for an hour and a half, destroying 35 homes and damaging over 200 more. The explosion of the pipeline was so great that the resulting crater was 40 feet deep and registered a magnitude 1.1 shockwave in the area.

The pipeline companies and the U.S. Department of Transportation recognize the potential for property damage and fatalities in populated areas from natural gas pipeline failure, designating an area near a pipeline as a High Consequence Area (HCA). Because the consequences of natural gas and hazardous liquid releases in populated areas are significantly different, the criteria for HCAs also differ. The determinants of an HCA and its width along a natural gas pipeline is a function of nearby population density and the distance from a potential explosion at which death, injury or significant property damage could occur. The distance at which potential death, injury or property damage can occur is called the potential impact radius. An HCA is an area within the potential impact radius with 20 or more structures for human occupancy or buildings that are hard to evacuate, such as a nursing home.

In many pipeline right-of-way condemnation cases, a common concern of property owners that will soon have a natural gas pipeline on their property or nearby is that future buyers of their property will capitalize the concerns about pipeline safety (stigma) into the home sale price, often bringing up the San Bruno explosion or other similar calamities to support their opinion. To obtain a sense of property owners' concerns regarding their property being condemned, the construction of a natural gas pipeline or proximity to a pipeline, one can Google a combination of pipeline, +fear, +property damage or +impact and one will find hundreds of thousands of entries. The fear of living near a natural gas pipeline sounds reasonable, especially after seeing the fire and devastation to homes due to a natural gas pipeline rupture. Put simply, before the installation of a natural gas pipeline near a home, there is no risk of a catastrophic event from a pipeline rupture and the home is not within an HCA; however, after the installation of a natural gas pipeline, the home is located within a HCA and there is a marginal increase in the risk of a catastrophic event.

For most people, a home is their largest investment, their financial nest egg, but a home also represents a bundle of non-pecuniary benefits that are just as important, if not more so. A home is a physical shelter from the elements, a place of emotional safety, and it provides a sense of place, a connection with the community. A marginal threat increase to this significant monetary asset or to the emotional aspects of home ownership should be reflected by an inverse relation between the sale price of a home and the proximity to the pipeline (i.e., the closer a home is to the source of the risk (pipeline), the lower the sale price). The purpose of this study is to ascertain if housing market participants perceive a nearby natural gas pipeline and location in a HCA as a negative externality and capitalize the increased risk of the externality into the house pricing decision.

Motivation

This analysis of a negative externality on the sales prices of housing is based on neighborhood preference. Every home is characterized by a combination of structural, neighborhood, and environmental characteristics that can be either positive or negative. Environmental characteristics have been identified in studies as proximity to parks, schools, shopping, and employment centers. Environmental characteristics that have been shown to have a negative effect on the sales price of homes have been proximity to refineries, manufacturing, airports, and landfills. The housing consumer is a wealth maximizer, always trying to choose a combination of housing, neighborhood, and environmental characteristics that maximize utility, subject to the consumer's housing budget. If a home's proximity to a natural gas pipeline is perceived as a negative characteristic of a home's location (environmental characteristic), then the magnitude of the market's capitalization of the externality into the sales price of the home will be revealed by the price paid for the bundle of environmental characteristics.

In general, homeowner fee simple real property rights are the right of use and enjoyment of the home, the right of exclusivity, and the right to transfer or not transfer the home.

Physical real estate is not bought or sold; only real property rights are transferred between the seller and buyer. Therefore, the diminishment of the quality of home ownership enjoyment because of its proximity to a natural gas pipeline should be capitalized into the sales price of the home.

Prior Studies and Pipeline Characteristics

Although there have been studies of the effect of a negative externality on the sales price of nearby housing (feed lot, nuclear power plant, landfill, pipeline rupture, etc.), the literature on the relation between the sales price of housing and proximity to a natural gas pipeline is meager, with only two published studies: Kinnard, Dickey, and Geckler (1994) and Diskin, Friedman, Peppas, and Peppas (2011).

The literature regarding stigma associated with a home's proximity to a negative externality can be divided into three broad categories: literature regarding a property that is near a source of odors or noise; literature regarding visual externalities—either positive externalities, such as lakes, mountains, and golf courses, or negative externalities, such as power plants, refineries, and high-voltage overhead powerlines; and literature regarding the negative externality resulting from proximity to a natural gas pipeline. The literature on pipelines can be further differentiated into the negative externality effect on the sales price of housing from a pipeline rupture (Simons, Winson-Geidman, and Mikelbank, 2001; Simons and Saginor, 2006) and the sales price effect of proximity to a natural gas pipeline that has not ruptured. It is the latter situation with which we are concerned here.

The location of a natural gas pipeline in an area is noted by above ground pipeline markers and warning signs at frequent intervals along the pipeline route and where the pipeline intersects a road, railway or waterway, as required by the U.S. Department of Transportation. The markers and warning signs denote the pipeline easement and the presence of the natural gas pipeline and provide a warning. The markers do not denote the exact location of the pipeline, just the location of the pipeline easement and the presence of the pipeline in the easement. The location of the pipeline is also noted by the presence of above ground valves, compressors, and above ground appurtenances along the route.

Since natural gas pipelines are usually underground and the presence is only noted by the aforementioned markers and above ground appurtenances, pipelines do not have an effect on the sales price of housing in the same way as high-voltage overhead powerlines, refineries, and power plants do by being a high profile constant visual reminder of the negative externality, but these types of properties are also a negative visual externality even without the marginal catastrophic risk.

As such, natural gas pipelines are not a visual externality and do not normally emit odors or noise in sufficient quantity or frequency to affect the sales prices of nearby homes. Thus, the externality associated with the presence of a natural gas pipeline is a product of the risk of a catastrophic pipeline rupture, resulting in the housing market capitalizing the risk into the sales prices of nearby housing. Therefore, a review of literature regarding externalities that are the source of noise or odor would not be illuminative of an underground natural gas pipeline as an externality. Studies of negative externalities, such as high-voltage transmission lines, power plants, and refineries, along with studies of positive externalities, such as ocean, lakes, and golf courses, provide ample evidence of the power and essentialness of visibility for a negative externality to have an effect on the sales prices of homes.

Kinnard (1991) and Kinnard, Dickey, and Geckler (1994) discuss the impact of a natural gas pipeline on the value of nearby homes. Kinnard, Dickey, and Geckler (1994) studied the effect of the proximity of a natural gas pipeline on the value of nearby housing in nine towns in Connecticut and also the effect of a pipeline on the value of housing in a master planned residential community in Las Vegas, Nevada.

In the Connecticut portion of the study, Kinnard, Dickey, and Geckler (1994) measured the effect of the pipeline on the value of homes within 5,280 feet of two pipelines, the Algonquin and the Tennessee lines. They divided the distance from the pipelines into eight zones. Zone T homes were traversed by the pipeline right of way and Zone O homes abutted the pipeline right of way. The remaining six zones were distance zones from the pipeline from 200 feet or less out to 5,280 feet. The authors performed a multiple regression analysis in the hedonic format with 1,117 home sales using the adjusted sale price of the home as the dependent variable. This model produced an adjusted R^2 of 0.7382, which is within acceptable parameters for a regression model using home sales data. They found a negative price effect on the value of homes that are transected by the pipeline easement; however, these effects were not significant. They also found a differing proximity effect of a pipeline on home value in the eight zones and even a differing pipeline impact on home value along the two pipelines, but overall there was no systemic home value pipeline distance pattern that was significant.

In the Las Vegas portion of the study, Kinnard, Dickey, and Geckler (1994) used 2,190 home sales and disaggregated the home sales into five distance zones. Again, they performed a multiple regression analysis in the hedonic format and found no systemic pattern of price differences until reaching 1,300 feet from the pipeline. This indication that the value of housing is less further from the pipeline is illogical with the premise that home value closer to the pipeline should have shown a negative price effect. This regression model using the adjusted sales price of the home as the dependent variable produced an adjusted R^2 of 0.8610. The authors concluded there was no pattern of measurable and significant negative impacts on the sales prices of housing close to an existing or proposed natural gas transmission pipeline and there was no systematic pattern of variation in the sales prices of homes near a natural gas pipeline.

Diskin, Friedman, Peppas, and Peppas (2011) studied the effect of the proximity of a natural gas pipeline on the sales prices of about 1,000 nearby homes in communities in Arizona. They used a matched pairs analysis, coming up with 168 pairs in three principal communities that are bisected by a natural gas pipeline. In sales data for each community, they found some indication that a pipeline had a negative effect on the sales price of a nearby home. But they also found that in the same community, using the same data, the natural gas pipeline was an amenity with either similar or greater occurrence. Thus, based on this paired sales analysis, the authors were of the opinion that there was no reasonably probable indication that the value of nearby housing was negatively affected by proximity to a natural gas pipeline.

Data

Our study is centered in northwest Hillsborough County in Florida where there is a 14-inch diameter natural gas pipeline that was constructed in 1959. Our data includes single-family home sales located within one mile of this pipeline, which is inclusive of the HCA area near the pipeline. When this natural gas pipeline was installed, northwest Hillsborough County was rural pasture and woodlands. In the 1970s, development sprawl migrated north from the City of Tampa to available land in the study area, and in the mid-1990s, several moderate to large scale subdivisions were built, contorting themselves around the pipeline. Observation of the recorded plats and personal inspection of the subdivisions evidenced the change in the rhythm of lot spacing and street regularity that was required to fit the subdivisions around the pipeline right-of-way. The integration of the subdivisions with the pipeline controls for possible biases that have been mentioned by others, such as bias from sales data near commercial development and along arterial rights-of-way.

The residential communities within the study area are generally single-family homes in planned residential communities on one-quarter-acre lots with small clusters of townhomes and apartment communities near or along arterial roads. The study area is mostly built-out with little land available for expansion of the housing stock and thus expansion of the population. As is common in most areas of the country, community scale retail is clustered by county zoning along arterial and collector roads in the area.

We obtained data from the Hillsborough County Property Appraiser for home sales that occurred between 2008 and 2013. We used all single-family home sales qualified by the Hillsborough County Property Appraiser using Florida Department of Revenue guidelines. ARCGIS version 10.1 was used to disaggregate home sales within one mile of the pipeline from all home sales that occurred in Hillsborough County during the study period and to calculate the shortest straight line distance of the home sale from the centerline of the pipeline easement. We also excluded from our dataset sales of homes that are bisected by the pipeline easement in order to achieve consistency in the property rights being analyzed, rights that are altered when encumbered with a pipeline easement. This resulted in a usable dataset of 1,059 home sales.

Seven structural independent variables are used to describe each home. They are lot acres, the age of the home at the time of sale, square footage of living area, bathrooms, finished square footage of garage area, square footage of screened or unscreened porch area, and the presence of a pool or spa. See Exhibit 1 for variable descriptions. To improve the interpretive power of the model and to account for diminishing marginal utility of property size, lot acres and square footage of living area have been transformed to their natural logarithm form. Two independent variables describe the demographic characteristics of the neighborhoods surrounding each home. They are 2007–2011 median household income, as reported by the American Community Survey, by Census block group, transformed to its natural logarithm form, and the percentage of elementary school students receiving free or subsidized lunches in the 2010–2011 school year, as reported by the Florida Department of Education, by Census block group. The transactional independent variables are binary variables that indicate the year in which the sale of the home occurred.

Exhibit 1. Description of Variables

Variable	Description
LN_PRICE	Natural logarithm of home sales price.
D_0_250, D_251_500, D_501_1000, D_1001_HALF	Series of binary variables indicating whether the property was located within one of four distance bands: edge of the pipeline easement to 250 feet from the centerline of the easement (28 homes), 251 to 500 feet from the centerline (60 homes), 501 to 1,000 feet from the centerline (103 homes), or 1,001 feet to one-half mile from the centerline (189 homes). These dummies are in relation to the furthest distance band, one-half mile to one mile from the centerline of the easement (679 homes).
LN_ACRES	Natural logarithm of the number of lot acres.
LN_AREA	Natural logarithm of square feet of living area.
BATH	Number of bathrooms.
AGE	Age of the home at the time of sale.
POOL_SPA	Binary variable indicating whether the home had a pool or a spa.
PORCH_100	Area in square feet of finished open and screened porch space/100 SF.
GARAGE_100	Area in square feet of finished garage space/100 SF.
LN_MHHINC	Natural logarithm of 2007–2011 median household income by Census block group geography.
PCT_FR	Percentage of elementary school students receiving free or reduced lunch in the 2010–2011 school year by Census block group geography.
2009–2013	Series of binary variables indicating the year of sale. These dummies are in relation to 2008.

The environmental variables are the variables of interest in our study. To estimate the expected change in the sales price of a home relative to its proximity to the natural gas pipeline, we constructed a vector of categorical variables denoting whether the homes fell into defined bands of distance from the pipeline. In the model, these distance bands are relative to homes located further than one-half mile from the natural gas pipeline. We chose this category to serve as the reference for the other distance bands because homes located furthest from the pipeline would be the least likely to be affected by the pipeline. This method of denoting distance categories, as opposed to using a continuous distance function, was chosen to specify the model because of the assumption that sales price does not change with distance from the pipeline at a constant marginal rate. The distance categories are zero to 250 feet from the pipeline, 251 to 500 feet from the pipeline, 501 to 1,000 feet from the pipeline, 1,001 feet to one-half mile from the pipeline, and the reference distance category, one-half mile to one mile from the pipeline.

Methodology

Housing is a differentiated product comprised of a bundle of housing, neighborhood, and environmental characteristics. The explicit sales price of a house reveals the sum of buyers' willingness to pay for these characteristics, and the implicit marginal prices of these characteristics can be revealed by the hedonic form of multiple regression analysis.

If buyers' value proximity to good schools or a two-car garage or they perceive a natural gas pipeline as a negative externality, the sales price of homes will reveal these preferences.

To estimate home buyers' preferences of proximity to a natural gas pipeline, a hedonic regression analysis was conducted. A hedonic regression analysis estimates the marginal difference in a dependent variable attributable to one or several independent variables, holding all else constant. Our first model is an employment of ordinary least squares (OLS) estimation. This model is used as a starting point for our spatial analyses.

Sirmans, Macpherson, and Zietz (2005) researched the frequency of common independent variables used in OLS regression analysis of housing and grouped them into structural, neighborhood, transactional, and environmental characteristics. The environmental characteristic of interest in this study is the distance to the underground natural gas pipeline, which is expressed as each home's position within a defined set of distance bands. The log-linear functional form of the hedonic model was chosen to allow for variation in the marginal value of each characteristic. Therefore, the OLS model is estimated as follows:

$$ln(P) = \beta_0 + S\beta_1 + N\beta_2 + T\beta_3 + D\beta_4 + \varepsilon, \quad (1)$$

where $ln(P)$ is the natural logarithm of the sale price of a home, β_0 is the regression intercept, S is a vector of structural characteristics, N is a vector of neighborhood characteristics, T is a vector of transactional characteristics, D is a vector of distance measures from the pipeline, and ε is the unobserved error term.

This OLS model is typical of models in the real estate literature, which aim to determine sales price effects on real estate of one or several associated factors. What the prevailing pipeline literature has not taken into account are the spatial relations between parcels of real estate serving as data in such empirical models. Statistical models with real estate components are subject to a significant degree of spatial autocorrelation, which is to say that the sales prices of homes tend to be similar to the sales prices of nearby homes. Tobler (1970) described it best, saying, ''Everything is related in space, but near things are more related than others.'' Spatial autocorrelation in a regression model can lead to unreliable parameter estimates, thus the spatial distribution of the data must be accounted for in order to properly specify such models.

To detect spatial autocorrelation, we employ Moran's I statistic. Moran's I statistic is a measure of autocorrelation due to spatial clustering of similar values. If spatial clustering in the OLS residuals is indicated, it is inferred that the specification of the OLS model presented previously is not reliable. Instead, this model will need to be improved upon by specifying it with respect to the spatial distribution of the data. Two models are presented that address this requirement: the spatial lag model and the spatial error model.

While the spatial lag model and the spatial error model both address the spatial autocorrelation inherent in the model using maximum likelihood estimation, they arrive at their conclusions via very distinct assumptions of the proper specification of the model. The spatial lag model assumes that values for the dependent variable are closely related to those values of nearby observations, thus the value indication of sales price for an observation depends not only on the independent variables but also on the spatially lagged values of sales price of that observation's neighbors (Anselin and Rey, 2014). The spatial lag model is specified as follows:

$$ln(y) = \rho W[ln(y)] + S\beta_1 + N\beta_2 + T\beta_3 + D\beta_4 + \varepsilon$$

$$\varepsilon \sim N(0, \sigma^2 I_n), \tag{2}$$

where ρ is the autoregressive parameter and W is a row-standardized connectivity matrix defined as follows:

$$W = w^*_{ij} = w_i / \Sigma_j w_{ij}. \tag{3}$$

Standardizing the spatial weights matrix, or dividing each spatial weight w_{ij} by the sum of the neighboring weights in each respective row, allows the weights to be applied proportionally across observations, effectively including consideration to observations with fewer neighbors relative to observations with more neighbors. In effect, it allows ''islands,'' or observations with few or no neighbors, to be included in the spatial process according to their degree of spatial influence, which mitigates bias resulting from spatially disparate observations.

The spatial error model operates on a different fundamental assumption: that the spatial dependence of the observations is based on unobserved independent variables contained within the error term. Thus, this model controls for autocorrelation in the errors that arise due to spatial dependence (Anselin and Rey, 2014). The spatial error model is specified as follows:

$$ln(P) = \beta_0 + S\beta_1 + N\beta_2 + T\beta_3 + D\beta_4 + \varepsilon$$

$$\varepsilon = \lambda W \varepsilon + u, \tag{4}$$

where λ is the autoregressive parameter, W is the row-standardized spatial weights matrix defined in equation (3), and u is spatially independent.

While these spatially autoregressive models differ in their underlying assumptions about the nature of the spatial autocorrelation, they both address the spatial dependence inherent in the data. The relative merit of one model over the other is examined using the Akaike information criterion (AIC).[3]

Results

The summary statistics are in Exhibit 2 and the results of the OLS and spatial models are in Exhibit 3. In the OLS model, the presence of unequal error variance was detected via White's general test, thus heteroscedasticity-robust standard errors were used to derive the *t*-statistics for each associated coefficient. The statistical significance of no variable changed as a result of using the robust standard errors. This regression had an R-squared value of 0.858 with an adjusted R-squared value of 0.856.

The variables of interest are *D_0_250*, *D_251_500*, *D_501_1000*, and *D_1001_HALF*, all of which are statistically insignificant with the exception of *D_1001_HALF*.

Exhibit 2. Summary Statistics

Variable	Mean	Median	Std. Dev.
Sales Price	183,744	148,000	94,999
Distance to Pipeline (ft)	3,028	3,218	1,560
Lot Acres	0.25	0.20	0.18
Living Area (SF)	2,094	1,870	762
Bathrooms	2.3	2.0	0.5
Age	25.3	27.0	7.1
Porch Area (SF)	166	80	182
Garage Area (SF)	392	420	175
Median Household Income	61,763	58,125	18,806
Percent Free or Reduced Lunch	56.2	52.8	15.4

Exhibit 3. Results

OLS		Spatial Lag		Spatial Error	
Variable	Coeff.	Variable	Coeff.	Variable	Coeff.
D_0_250	−0.002	*D_0_250*	−0.032	*D_0_250*	−0.030
D_251_500	0.024	*D_251_500*	0.009	*D_250_500*	−0.004
D_501_1000	0.016	*D_501_1000*	−0.001	*D_500_1000*	−0.021
D_1001_HALF	0.056***	*D_1001_HALF*	0.016	*D_1000_HALF*	0.012
LN_ACRES	0.054***	*LN_ACRES*	0.055***	*LN_ACRES*	0.078***
LN_AREA	0.788***	*LN_AREA*	0.655***	*LN_AREA*	0.698***
BATH	0.059***	*BATH*	0.047***	*BATH*	0.051***
AGE	−0.004***	*AGE*	−0.005***	*AGE*	−0.006***
POOL_SPA	0.128***	*POOL_SPA*	0.112***	*POOL_SPA*	0.091***
PORCH_100	0.014***	*PORCH_100*	0.007	*PORCH_100*	0.006
GARAGE_100	0.027***	*GARAGE_100*	0.018***	*GARAGE_100*	0.021***
LN_MHHINC	0.087***	*LN_MHHINC*	−0.015	*LN_MHHINC*	0.085**
PCT_FR	−0.002***	*PCT_FR*	−0.001	*PCT_FR*	−0.002**
2009	−0.181***	*2009*	−0.192***	*2009*	−0.188***
2010	−0.226***	*2010*	−0.236***	*2010*	−0.234***
2011	−0.261***	*2011*	−0.273***	*2011*	−0.268***
2012	−0.235***	*2012*	−0.252***	*2012*	−0.243***
2013	−0.144***	*2013*	−0.152***	*2013*	−0.149***
Constant	5.235***	Rho	0.338***	Lambda	0.766***
		Constant	3.356***	Constant	6.144***

Note:
** Significant at the 95% level
*** Significant at the 99% level.

Interestingly, the coefficient of this variable has the opposite sign as expected, indicating that homes within the 1,000 feet to one-half mile distance category from the pipeline are expected to have a higher sales price than homes in the furthest distance category. However, this relative price difference is merely an illusion attributable to the spatial limitations of the OLS model, not the relative proximity to the natural gas pipeline.

Moran's *I* statistic, calculated based on the residuals of the OLS model, has a value of 0.165 with a z-score of 9.146 and a corresponding *p*-value of less than 0.000. The Moran's *I* statistic thus indicates that spatial autocorrelation is highly prevalent in the model. To account for the present spatial autocorrelation, we conduct an analysis of the spatial lag and spatial error models.

In both spatial models, all of the distance variables are statistically insignificant. This diverges from our conclusions from the OLS model whereby *D_1001_HALF* is statistically significant and positive, indicating that homes in the second-farthest distance band sold for a higher price than homes in the farthest distance band. The spatial lag and error models have given cause to reject that conclusion in favor of the conclusion that there is no statistically significant relation between the expected sales price of a home and its distance from the natural gas pipeline.

Interestingly, in the spatial lag model, both of the neighborhood variables, *LN_MHHINC* and *PCT_FR*, are not statistically significant, a further deviation from the OLS model. *PORCH_100* is also statistically insignificant in both spatial models. The sign of the coefficients of each of the structural, neighborhood, and transactional variables did not change from the OLS model to the spatial models with the exception of *LN_MHHINC* in the spatial lag model, which is not statistically significant. The sign on *D_251_500* changed from positive to negative in the spatial lag model, and the sign on both *D_251_500* and *D_501_1000* changed from positive to negative in the spatial error model, but their *p*-values of 0.956, 0.921, and 0.598, respectively, render these changes inconsequential.

In the spatial lag model, the autocorrelation parameter Rho is statistically significant with a value of 0.338, indicating that spatial autocorrelation is prevalent in the lagged sales prices of homes in the sample. The corresponding parameter Lambda in the spatial error model is also statistically significant with a value of 0.766, indicating that spatial autocorrelation is prevalent in the errors in the original OLS model. Due to the apparent presence of spatial autocorrelation as evidenced both by the Moran's *I* statistic and by the statistically significant autocorrelation parameters, it is prudent to control for the spatial autocorrelation as we have done.

These spatial models show an improvement in overall model fit, relative to the original OLS regression. This is indicated by the log-likelihood statistic, 282.978 in the OLS model, which increased to 339.564 and 333.085 in the spatial lag and spatial error models, respectively. However, the Breusch-Pagan test indicated the presence of heteroscedasticity in both of the spatial models, and the likelihood ratio test for spatial dependence is significant in both models, indicating that while the model fit improved in the spatial lag and error models, the spatial dependence is not entirely mitigated.

To compare the spatial lag and spatial error models against each other, we use the AIC. The spatial lag model has an AIC of −639.127, versus the spatial error model's AIC of

−628.17, indicating the spatial lag model is a slightly better fit than the spatial error model. This implies that the observed spatial autocorrelation has a stronger association as a function of the dependent variable as opposed to the error term.

Conclusion

Our findings suggest that, in general, home buyers do not factor proximity to an underground natural gas pipeline into their purchase decisions. We suspect that the reason for the lack of a price effect is primarily visual. Environmental disamenities such as high-voltage power lines and cell phone towers have an apparent negative effect on the sales price of surrounding homes, but these effects can be attributed to the high profile visible nature of these disamenities, while an underground natural gas pipeline itself is not visible, only the marker signs of the pipeline are visible. In other words, underground natural gas pipelines lack a constant visual reminder of their presence and risk (in comparison to, for instance, the visual impact of high-voltage transmission lines or the environmental impact of a municipal garbage incinerator); home buyers have a general understanding of their presence, but as the models show, if the pipeline is out of sight, the higher risk associated with living near one is not omnipresent.

Our data exhibit significant spatial autocorrelation; to address this, two spatially autoregressive models are used. While these models did improve the model fit relative to the original OLS model, some spatial dependence remains unmitigated. Thus, further research is merited. However, given our results, it is reasonable to suggest that underground natural gas pipelines do not have an observable effect on the sales prices of nearby homes.

Endnotes

[1] 2016 North American Pipeline Outlook. January, 2016. Retrieved from https://ucononline.com/.

[2] Safe Pipeline FAQ. U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration. Retrieved from http://www.phmsa.dot.gov/portal/site/PHMSA/menuitem.ebdc7a8a7e39f2e55cf2031050248a0c/?vgnextoid=2c6924cc45ea4110VgnVCM1000009ed07898RCRD&vgnextchannel=f7280665b91ac010VgnVCM1000008049a8c0RCRD&vgnextfmt=print.

[3] All models, tests, and analysis were conducted using GeoDa, a spatial data analysis software package developed by the Spatial Analysis Laboratory of the University of Illinois at Urbana/Champaign, the technical and mathematical components of which are described in Anselin and Rey (2014).

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