# Using Hedonic and Quasi-Experimental Methods in (Dis)Amenity Valuation with Housing Data: The Case of Communication Antennas

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**Abstract**

The purpose of this paper is to apply hedonic and quasi-experimental methods to measure the value of any disamenity caused by communication antennas. Spatial fixed effects are used to control for unobservable characteristics that can influence where both residents and antennas are located. Panel data techniques are used to address both time invariant and time varying unobservables and account for possible changes in the hedonic price function after construction of a nearby antenna. In contrast to estimates based on a cross-section hedonic without fixed effects, our estimates indicate that houses near communication antennas sell for less than comparable houses located farther away. A specification that considers distance to the nearest communication antennas as well as density shows that both are critical in determining the impact of localized disamenities on residential property values. Estimates from a repeat sales specification that relaxes the assumption of time-invariant housing characteristics was estimated and provides estimates similar to the cross section specification with fixed effects. A generalized difference-in-difference estimator was also estimated, but effects were statistically insignificant. One reason might be the difficulty in establishing treatment and control groups when properties are affected by multiple antennas. Multiple Listing Service data for more than 141,000 sales during the 2000-2011 period for areas in Central Kentucky are augmented by Federal Communications Commission Antenna Structure Registration data that give antenna characteristics, date of construction, date of dismantling, and latitude and longitude. The best estimate of the disamenity value associated with communication antennas suggests that a house within 1,000 feet of the nearest antenna when it is sold will sell for 0.54% ($992) less than a similar house that is 4,500 feet from the nearest antenna. This implies an aggregate reduction in sales price of approximately $2.29 million dollars for properties located within 1000 feet of a communication antenna.

## 1 Introduction

Cell phone usage worldwide and especially in the United States is growing faster than ever. In December of 1997 it was estimated there were 55.3 million wireless subscribers. Fifteen years later in December 2012, that number was estimated to be 326.4 million (CTIA-The Wireless Association (2013)). To put this in perspective, the United States Census Bureau estimated the population to be 267.8 million in 1997 and 319.9 million in 2012. This means the United States has gone from 20.6% of the population having a wireless subscription in 1997 to more than one subscription per individual in 2012. With the advances in mobile technology it is possible to do nearly every task that was once only possible on a desktop computer on a mobile device that fits in the palm of a hand. Like any other good or service, the added convenience of mobile technology has costs.

An area that has received little attention in the economics literature is the disamenity associated with the structures on which these antennas are mounted. As the demand for cell phones and mobile technology increases, it is followed by an increase in demand for reliable coverage, which in turn leads to an increase in the number of antennas. Beginning in the mid-1990's there was a sharp increase in the number of antenna structures which roughly corresponds to the time when mobile phone technology became more prevalent. Choosing the location for an antenna involves conflicting incentives for residents. Land owners may want to have an antenna located on their property since it provides an additional source of income and better cell phone reception for residents in its vicinity[1]. However, these structures are not pleasant to look at and residents tend to object to having them located nearby because of the visual disamenity they create or because of any adverse health effects they associate with the antennas[2].

[1] Airwave Management LLC. provides some insight into the amount of income these cell phone towers can generate for a land owner. According to their website, payments can reach as high as $60,000 per year.

[2] Despite concerns about negative health effects from the radio waves emitted from mobile devices, a comprehensive study of the health effects related to cell phone and cell phone antennas by Röösli et al. (2010) finds that there is no conclusive evidence that using cell phones or living near cell phone towers harms human health. Nevertheless, the perception of such risks may be sufficient to alter ones behavior.

Figures 1a and 1b illustrate when an externality is likely to exist, and the situation when a nearby antenna could provide a net benefit to nearby residents. In Figure 1a, an antenna is located on a property adjacent to a residential subdivision. Regardless of any compensation, the antenna structure is likely to be considered a disamenity by nearby residents[3]. Figure 1b shows an antenna that could provide a net benefit to nearby residents. The structure located at point A is hidden behind a thicket of trees and far enough away from the nearest neighbor (point C) to impose any cost. If the owner of the property at point B owns the land where the antenna is located, the owner is receiving payments from the antenna's owner, while nearby residents receive the benefit of improved coverage. In this situation the potential disamenity is mitigated by trees. Having an antenna located nearby should not decrease property values; it probably increases property values where the antennas are located.

The purpose of this paper is to apply hedonic and quasi-experimental methods to measure any disamenity caused by communication antennas controlling for endogenous antenna location and changes in unobserved housing and neighborhood characteristics. Spatial fixed effects are used to control for any time invariant unobservables that are correlated with proximity to an antenna. The repeat sales method and quasi-experimental techniques are used to address time invariant and time varying unobserved characteristics that could affect the equilibrium hedonic price function. Quasi-experimental techniques are becoming increasingly common in the environmental economics literature and are used instead of instrumental variables when there is not random assignment into treatment and control groups(Greenstone and Gayer, 2009).

[3] If the structure was constructed *before* the residents moved in or built a house in this subdivision, no uncompensated externality exists. They have preferences such that the structure does not affect them, or they were compensated for the visual aspect of the structure though a lower purchase price. However, if the structure was constructed *after* the residents moved in or built in this subdivision, they are affected by the sight of the structure and a lower sales price if they do decide to sell the property. The land owner where the structure is located is receiving payments from the antenna's owner, while all affected nearby residents are not being compensated.

## 2 Recent Work on Valuing Amenities/Disamenities

Omitted variables are a constant concern when estimating hedonic price functions. Following Rosen (1974), the hedonic price function of property $i$ can be represented by $P_i = P(S_i, N_i, Q_i)$ where $P_i$ is the price of property $i$. $S_i$, $N_i$, and $Q_i$ are the structural, neighborhood, and environmental characteristics, respectively. Consumers have utility $U = U(X, S_i, N_i, Q_i)$ which is maximized subject to the budget constraint $P_i + X = M$, where X is a Hicksian composite commodity with price equal to \$1, and M is income. This gives the following first order condition:

$$(\partial U/\partial Q_i)/(\partial U/\partial X) = \frac{\partial P_i}{\partial Q} \tag{1}$$

This says the marginal rate of substitution between the environmental characteristic and the composite good X is equal to the slope of the hedonic price function (market clearing locus) in the environmental characteristic $Q_i$. Once the hedonic price function $P_i$ has been estimated, the partial derivative of $P_i$ with respect to the environmental characteristic $Q_i$ is equal to the implicit price of the environmental characteristic. However, when there are characteristics unavoidably omitted from $P_i$ that are correlated with $Q_i$, the estimate of willingness to pay for $Q_i$ will be biased. Endogeneity in the location of the antenna structures is the greatest concern in estimation. Holding all else constant, owners of the antenna structures are going to locate them in areas where it costs the least. If not taken into account, this will lead to an overestimate of the negative impact these structures have on property values. Other issues that have to be addressed in estimation concern buyers sorting and the stability of the hedonic price function. To address the sorting concern, spatial fixed effects are included to control for unobservables that may influence both buyer's location choices and the location of communication antennas. The most recent panel data techniques that address both time-invariant and time-varying unobservables are used to account for the possibility of a changing hedonic price function after the construction of a nearby antenna.

Rosen (1974) makes two critical assumptions in his characterization of the hedonic equilibrium. The first is that buyers have complete information about their available alternatives. In the study of housing markets, this implies that consumers have perfect information about local amenities and disamenities. Currie et al. (2013) check this assumption by estimating the external costs associated with the opening and closing of toxic industrial facilities. They compare the willingness to pay to avoid these facilities (estimated using housing data) to the costs associated with the increased incidence of children born with low birth weight caused by the same toxic facilities. They estimate an aggregate reduction in housing values per plant of $1.5 million within a one mile radius, and costs associated with the increased incidence of low birth weight of about $700,000. Since the reduction in property values reflect the costs associated with adverse health effects along with factors such as increased congestion, the visual disamenity associated with the facilities, decreased utility from outdoor activity, they conclude that the evidence fails to contradict the assumption of unbiased or perfect information in the housing market. Since the disamentiy associated with communication antennas is visual, and the antenna structures are highly visible, the assumption of full information is appropriate for this study.

The second assumption is that households move freely among locations, and that consumers have homogeneous preferences over the bundle of goods being purchased. Cameron and McConnaha (2006) find evidence that households do migrate in response to perceived changes in environmental conditions. Bayer et al. (2009) find that the estimates of willingness to pay for a reduction in ambient concentrations of particulate matter that incorporate the cost of moving are three times greater than the estimates from a conventional hedonic model using the same data. Bieri et al. (2012) use the 5% public use sample from the 2000 Census that contain the housing prices, wages, and location specific amenities for over 5 million households to estimate aggregate amenity expenditures for the United States. The precise household level data allow them to relax the assumption of homogeneous households and to precisely estimate the cost of moving between possible locations. Their preferred estimates come from a specification that uses historical migration data for each location to identify a consideration set of possible locations for each household combined with location to location specific moving costs. They show that the estimates of aggregate amenity expenditures are sensitive to the way in which migration is modeled. Kuminoff et al. (2012) provide an overview of the current state of the equilibrium sorting literature housing markets. All four of these studies suggest that estimates of disamenity value should consider migration, sorting, and changes over time.

While Rosen (1974) shows that the partial derivative of $P_i$ with respect to $Q_i$ provides an estimate of the willingness to pay for a small change in the environmental good $Q_i$, the appropriate functional form for the hedonic price function is uncertain. Cropper et al. (1988) use simulations to see determine how different functional forms perform when there are omitted variables in the hedonic price regression. They find that flexible functional forms perform well when all of the attributes are included, but recommend using a more parsimonious functional form when there are omitted variables. The linear, semi-log, double-log, and linear Box-Cox functional forms have remained the most prevalent functional forms used to estimate the marginal willingness to pay for environmental amenities to reduce bias caused by omitted variables.

Since Cropper et al. (1988), sample sizes have increased dramatically, advances in geographical information systems allow researchers to control for previously unobserved spatial characteristics, unobserved structural housing characteristics are much less of a concern, and quasi-experimental techniques have become more prevalent. Kuminoff et al. (2010) use a theoretically consistent Monte Carlo framework to test the performance of six functional forms when time-varying and time-constant spatial variables are omitted. After addressing advances, Kuminoff et al. (2010) find that the recommendations in Cropper et al. (1988) should be reconsidered. When using cross-section data, Kuminoff et al. (2010) find that the quadratic Box-Cox functional form with spatial fixed effects performs best. However, for practical purposes, including spatial fixed effects significantly reduces bias regardless of the functional form used[4].

[4]Since the quadratic Box-Cox is still computationally intensive and the coefficients are difficult to interpret, semi-log

Kuminoff et al. (2010) also show that exploiting variation in an environmental amenity for properties that sell multiple times can reduce bias in willingness to pay estimates compared to pooled OLS with fixed effects. If the spatially correlated unobservables are time invariant, their effect will be purged from the model when first differences are taken. However, if the unobservables are not time invariant, the estimates from a repeat sales model will be biased. Repeat sales models have recently been used to estimate the impact of changing cancer risks (Gayer et al., 2002), the siting of wind farms (Heintzelman and Tuttle, 2012), Superfund site remediation (Mastromonaco, 2011), and reductions in three of the Environmental Protection Agency's criteria air pollutants (Bajari et al., 2012).

Kuminoff et al. (2010) find that a generalized difference-in-difference estimator with interactions between the time dummy variables and housing characteristics to allow the shape of the price function to change over time performs best when panel data are available. Linden and Rockoff (2008) provide a technique for defining treatment and control groups so that difference-in-differences can be used to estimate the impact of environmental (dis)amenities when treatment and control groups are not clearly defined. They used this technique to define treatment and control groups to estimate the willingness to pay to avoid living near a registered sex offender. Their technique has recently been used to estimate the impact of brownfield remediation (Haninger et al., 2012) and shale gas developments (Muehlenbachs et al., 2012)[5]. Parmeter and Pope (2012) provide a thorough overview of difference-in-difference method and other quasi-experimental techniques. By differencing over time, the difference-in-difference method controls for time invariant unobservables just like the fixed effects and repeat sales methods, but also overcomes problems with time-varying unobservables with the "common

and linear Box-Cox models are commonly used.

[5]Muehlenbachs et al. (2012) use a difference-in-difference-in-differences model. They use the Linden and Rockoff (2008) technique to find the distance at which shale gas developments do not impact property values, but also use the local public water service area to define a second treatment group. Similar to owners of land where shale gas wells are drilled, owners of land where communication antennas are located receive payments from the antenna's owner. Assuming that conditional on a property's observable characteristics and being within 2000 meters of a drilled well, every property has an equal chance of receiving lease payments regardless of water source, they are able to separate the impact of lease payments and decreased water quality.

trends" assumption. While this assumption cannot be formally tested, Linden and Rockoff (2008) provide visual evidence that it holds in their study. Once treatment and control groups are defined, they plot housing prices against the days relative to a sex offender's arrival. Since prices in the control group trend similarly before and after offenders arrive, but prices in the treatment group fall significantly, they are confident they have identified a valid control group. A similar approach will be used here[6].

Hedonic property value models are used to estimate the marginal willingness to pay for environmental amenities, $\partial P_i / \partial Q$. While there are advantages of using the repeat sales method and quasi-experimental techniques to eliminate the bias caused by time-invariant unobservables, these methods estimate a capitalization rate that is not necessarily equal to the marginal willingness to pay. It is possible that the presence of, or change in an environmental (dis)amenity can cause the hedonic price function to change over time. Kuminoff and Pope (2012) and Haninger et al. (2012) show that as long as the hedonic price function is constant over time, there should be no difference between the capitalization rate and the marginal willingness to pay. Given that the communication antennas are expected to have relatively small impacts on property values, it is unlikely that the construction of a new antenna structure will lead to a change in the hedonic price function. But, this issue will be addressed.

Mastromonaco (2011) and Bajari et al. (2012) both propose methods for reducing bias caused by time-varying spatially correlated unobservables. Mastromonaco (2011) includes census tract-year fixed effects that allow the effect of unobservables at the neighborhood level to vary over time in a repeat sales model. Bajari et al. (2012) also use a repeat sales model, but exploit information contained in the residual from the first sale to learn about the characteristics of the house that the researcher cannot observe directly. Specifically, they argue that after controlling for the characteristics that are observable, if the sales price was abnormally positive (negative) the first time it was sold, this value of the characteristics that were not observed is positive (negative).

[6] In this study, a majority of communication antennas were built several years before the property is sold making a visual check of the "common trends" assumption difficult.

They show that not controlling for time-varying unobservables leads to estimates of willingness to pay for reductions in air pollution that are considerably smaller than when these unobservables are considered. Bajari et al. (2012) are not able to control for changes in house characteristics directly because they have characteristics for the last sale only. In contrast the data used in this study has house characteristics at the time of each sale and allows for control of changes in them. The results below show that the unobservables that are correlated with proximity to a communication antenna are time invariant and are adequately controlled for using spatial fixed effects.

## 3 Data on Housing and Antennas

Housing data cover a period of 12 years from 2000 to 2011 and were extracted from two Multiple Listing Services that serve the Louisville and Elizabethtown areas in central Kentucky. The housing data contain an extensive set of structural housing characteristics, closing dates, and sales price for every property sold. All property addresses were geocoded using a program that accessed MapQuest and provided a standardized address and latitude and longitude for each property[7]. This standardized address is used to identify houses that are sold multiple times.

These data are much richer than data extracted from a local Property Valuation Administrator or data from DataQuick that are commonly used. While data from each of those sources identify properties that are sold more than once, the structural housing characteristics are only recorded for the most recent transaction. The data used here identify properties that are sold more than once during the sample period and record the structural housing characteristics each time the property is sold. This detail allows for a check of the assumption that structural housing characteristics are constant over time, an assumption that is often made when using the repeat sales method.

[7]One issue with geocoding addresses is that the coordinates will correspond to the location on the street where the property is located and not the exact coordinates of the actual house; Filippova and Rehm (2011) were able to overcome this using the coordinates where the home was located within the plot. In the current study, properties that were not assigned a standardized address and a unique latitude and longitude were excluded from the final sample. Properties with less than 500 square feet or more than 10,000 square feet or zero bedrooms or zero full baths were also dropped.

Data for the communication antennas come from the Federal Communication Commission's (FCC) Antenna Structure Registration database. This database includes all communication antennas in the United States that are registered with the FCC. All antennas that may interfere with air traffic must be registered with the FCC to make sure the lighting and painting requirements are met. These data contain antenna characteristics such as dates for construction and demolition, latitude and longitude, antenna height, and antenna type. It is possible there are antennas located in the study area that are not registered, but this is rare. Since the construction date for each antenna needs to be known to ensure the antennas located near houses were standing when the property sold, antennas that did not include a construction date were dropped[8]. In this study, data cover a large area. Google Earth was used to verify whether or not an antenna was standing when the property sold if there was a dismantled date recorded. Since the images include the date the image was captured, it was possible to identify whether or not the antenna was standing when the property sold[9].

ArcGIS was used to determine several location-specific characteristics. They include (1) the census tract in which each house is located, (2) the census block group in which each house is located, (3) distance to the nearest communication antenna, (4) distance to the nearest parkway/interstate, (5) distance to the nearest railroad, and (6) distance to the Fort Knox military base. Since the visual disamenity of communication antennas is the focus of this study, all proximity measures were calculated using straight line distances. All antennas within a ten mile radius of each property that were standing when the property was sold were identified. This information was used to determine the number of antennas located within specified distances from each property.

[8]Since the earliest construction year in the sample of antennas is 1927 and the latest 2011, it cannot be assumed that the absence of a construction date means the antennas with missing dates were built before the year 2000 and can be included in the final sample.

[9]This was a concern for only a handful of antennas. Multiple antennas were assigned the same coordinates and it was determined that this corresponded to multiple antennas being mounted on the same structure. Some demolition dates indicated that an antenna was removed, and some demolition dates indicated that the actual structure was taken down. Being dismantled refers to the latter.

Summary statistics for the housing characteristics are given in Table 1. The typical house sold for $183,619, has three bedrooms, two full bathrooms, is 1,655 square feet in size, has a lot size of about eight-tenths of an acre, and is 33 years old. Holding all else constant, the owner of a communication antenna will attempt to locate the antenna in an area that minimizes the owner's cost. To check if antennas are located in areas where property values are low to begin with, Table 2 shows summary statistics for houses within and beyond 4,500 feet of an antenna[10]. Houses within 4,500 feet of an antenna sell for $32,979 (16%) less than a house more than 4,500 feet away, have slightly fewer bedrooms and bathrooms, are smaller, and are on smaller lots. The most notable difference is that houses within 4,500 feet of an antenna are about 18 years older on average than houses more than 4,500 feet away from an antenna. It appears that communication antennas are in fact located in areas where properties are less valuable. While most of the difference in sales prices for houses within and beyond 4,500 feet of a tower can be explained by differences in the types of houses, the primary focus of this study is controlling for differences that are unobservable. The precise location information for each house provided in the data is used to control for these unobservables[11].

Summary statistics for the proximity measures of all antennas are shown in Table 3[12]. The average house is located 5,794 feet (1.1 miles) away from the nearest antenna, with a median value of 4,500 feet (.85 miles). Only 0.6% of houses are within 600 feet of their nearest antenna, and 12.4% of the houses in the sample have antennas within 2,100 feet. The lower panel in Table 3 summarizes the number antennas that are located within certain distances from each house. While the majority of houses only have one antenna within each radius, there are are non-trivial number of houses that are likely affected by the presence of multiple antennas. For example, there are 204

[10]4,500 feet is approximately the median value of distance to the nearest standing antenna in this sample.

[11]A regression of the number of communication antennas in a census tract on the median sales price and census tract demographics suggest that the number of antennas in a census tract is negatively correlated with property values. However, even though the coefficient has the expected sign, the coefficient is not statistically different from zero at conventional levels, and the median sales price and demographics only explain 8% of the variation in the number of communication antennas in a census tract.

[12]Antennas refer to all of the structures in the sample regardless of their type. Towers refer to the largest type of structure that are the most visually disruptive due to their size and the distance at which they can be seen. Summary statistics for only tower type structures are shown in Table A1.

houses that have two antennas within 1,500 to 1,800 feet, and 9 that have 3 antennas within that same radius. This means that estimating the disamentity value caused by communication antennas using distance to the nearest antenna could be biased due to the presence of multiple antennas. Estimates would tend to be biased upwards because all the value of the disamenity would be attributed to the nearest antenna when it should be attributed to the combination of antennas.

Before moving to estimation of any disamenity value of antennas, it is worth addressing an overall concern about housing market analysis during the Great Recession. The concern is how an equilibrium framework such as that in Rosen (1974) can produce misleading results during a period of disruption[13]. Without question housing prices declined between 2006 and 2009, but as Carson and Dastrup (2013) report there was considerable spatial variation. Across metropolitan areas, housing prices declined none at all to more than 60%.

The four-quarter percent change in the Federal Housing Finance Agency's housing price index is shown in Figure 2 for the study area and the Los Angeles and Miami Metropolitan statistical areas (MSA). Even though the Louisville MSA was affected by the recent housing crisis, house prices remained relatively stable compared to the larger MSAs that were affected the most. This stability minimizes concerns that the results presented below are being affected by a rapidly changing and unstable housing market. Changes in demographic characteristics for the study from 2000 to 2010 are compared to changes for the entire United States in Table 4. The only notable difference is that unemployment more than doubled nationally while there was only a 62% increase in the study area. For the entire United States, the percent change in the number of people who moved from out of state fell by 71% while it increased by 12% in the study area; since the study area contains the Fort Knox military base, the above average number of out-of-state movers is to be expected[14].

[13]This issue is discussed in detail in Boyle et al. (2012).

[14]A regression of the change in the number of communication antennas in a census tract on the percent changes in demographic characteristic the same tract suggests that changes in demographics are not leading to significant changes in the number of communication antennas in an area. There were statistically significant coefficients on median income, unemployment, percent of the population that owns their home, and the percentage of the population with a bachelor's degree or higher. However, the changes in these characteristics required to cause one additional antenna to be constructed or dismantled are extremely large. For example, it would take a 1,067% increase in

## 4 Empirical Model

To determine the impact proximity to an antenna structure has on property values, hedonic property value models and quasi-experimental methods are used. The first regressions rely on cross-sectional variation in distance to the nearest antenna and do not exploit the panel aspect of the data. The second set of regressions exploit the panel aspect of the data to reduce the potential bias caused by time invariant unobservables. The data cover a period of twelve years with communication antennas being built and dismantled throughout the period as well as in between sales of the same property. These changes allow for estimation of the traditional cross section specifications as well as the repeat sales and difference-in-difference specifications that are becoming more prevalent in the hedonic literature (Gayer et al. (2002); Linden and Rockoff (2008); Parmeter and Pope (2012); Haninger et al. (2012); Muehlenbachs et al. (2012); Bajari et al. (2012)).

### 4.1 Cross-Section Specification and Proximity Measures

Following Kuminoff et al. (2010) and Heintzelman and Tuttle (2012), a semi-log specification with spatial fixed effects is used to address the potential bias caused by time invariant, spatially correlated unobservables. The first specification is:

$$\ln P_{ijt} = z_{ijt}\beta + x_{ijt}\delta + \lambda_t + \gamma_j + \epsilon_{ijt} \tag{2}$$

where $z_{ijt}$ is the set of variables describing proximity to the nearest antenna structures, $x_{ijt}$ includes an extensive set of structural housing characteristics, $\lambda_t$ are year-month time dummy variables, $\gamma_j$ are spatial fixed effects, and $\epsilon_{ijt}$ is the error term. To demonstrate the importance of including the spatial fixed effects, equation (2) will be estimated without spatial fixed effects and again with census tract or census block group fixed effects. If there are unobserved spatial characteristics that are correlated with the proximity variables, $\beta$ in equation (2) should be more

unemployment to lead to the dismantling of one antenna.

precisely estimated the tighter the fixed effect.

Three proximity measures are used that allow distance to a communication antenna to have a non-linear effect on the sales price of a house. The first is a continuous, quadratic measure of distance to the antenna nearest a property when it was sold[15]. By including distance and distance squared in the regression, the point at which an antenna has no effect on property values can be estimated. The spatial fixed effects ensure that this continuous measure of distance is measuring the impact of a nearby antenna and not proximity to an area that may be a magnet for communication antennas. As a robustness check, the inverse of distance to the nearest antenna that was standing when the property sold is also used.

The second measure is a set of dummy variables equal to one if the nearest antenna is located within some specified radius from the property and is similar the method used in Heintzelman and Tuttle (2012). Distance bands of 300 feet are used and the base category is the situation in which the closest antenna structure is more than 4,500 feet away. This specification allow for a discrete non-linear effect of distance to the nearest tower, however, there is no rule of thumb as to the width of distance bands that should be used or the distance from an antenna that should be used as the base category. Distance bands of 300 feet are used because they are sufficiently large to contain enough antennas to provide the variation needed to precisely estimate their effect, but small enough to allow for a higher degree of non-linearity than larger rings would allow. Houses more than 4,500 feet away from an antenna were chosen as the base category since this is the median value for distance to the nearest antenna.

The third measure uses the same 300 foot distance bands used in the previous method but counts the number of antennas located within a specified radius of the property. Mastromonaco (2011) uses this type of proximity measure to estimate the impact of Superfund sites on property values in Greater Los Angeles area of California. He points out that using the distance to the nearest site

[15]This method is used in Banfi et al. (2008), Bond (2007b), and Bond (2007a) to estimate the impact of cell phone towers on property values.

ignores the presence of additional nearby sites that could bias the results upward if only the nearest site is considered. By estimating the average impact of all nearby sites, some of the bias inherent in the nearest site method can be removed. If each house has only one antenna within a specified radius, this method would provide estimates identical to the nearest site method using dummy variables equal to one if an antenna is located within the specified radius. The summary statistics in Table 3 show that there are multiple properties that will be affected by the presence of multiple antennas. Including the number of antennas within in specified distance bands provides estimates of the marginal impact of adding one additional antenna within a specified distance, and this effect is allowed to vary with distance.

### 4.2 Panel Analysis - Repeat Sales and Difference-in-Differences

One strategy for removing time invariant unobservables is exploiting the variation in distance to the nearest antenna for properties that sell multiple times. During the study period, new antennas were constructed and old antennas were dismantled. This allows for variation in distance to the nearest antenna over time for the same property. This approach eliminates any time invariant unobservables that may be correlated with the proximity variables and is is the primary method used in Gayer et al. (2002), Heintzelman and Tuttle (2012), Mastromonaco (2011), and Bajari et al. (2012). The following regression is estimated:

$$\ln P_{it} - \ln P_{it'} = (z_{it} - z_{it'})\beta + (x_{it} - x_{it'})\delta + \lambda_t + \epsilon_{it} - \epsilon_{it'} \tag{3}$$

where $z_{it}$ is the distance to the nearest standing antenna at time $t$, $x_{it}$ are structural housing characteristics that may vary over time. Following Gayer et al. (2002), $\lambda_t$ is a set of year variables equal to -1 if the year indicates the first year the property sold, 1 if the year indicates the year of the last sale, and 0 for all other sales[16]. This allows for appreciation in housing values over time. $\epsilon_{it}$ is the error term. This specification is different from the repeat sales model that is typically

[16] Bailey et al. (1963) introduce this method of estimating a price index using a repeat sales framework. The first period (year 2000) is the base year and the remaining coefficients can be interpreted as the log price index.

estimated. In the typical repeat sales model, only the proximity variables that measure distance to the nearest antenna would be allowed to vary over time while the structural housing characteristics are assumed to be constant. Some previous studies that use the repeat sales method use data from a source similar to this study and have housing characteristics at the time of each sale (Gayer et al., 2002). However, several recent studies use data from sources that do not record the structural housing characteristics each time a house is sold and make the assumption of constant structural characteristics (Heintzelman and Tuttle (2012); Mastromonaco (2011); Bajari et al. (2012)). The number of observations in the sample that have structural housing characteristics that change over time are shown in Table 5. Of the 26,579 houses that sold more than once, a non trivial number experienced a change in a major structural characteristic between sales. For example, 4,311 (17%) of houses had a change in the number of bedrooms between sales. Equation 3 will be estimated with and without the changing structural housing characteristics to control for changes and determine how sensitive the estimate of $\beta$ is to the assumption of constant structural characteristics.

There are shortcomings when using the repeat sales approach. There is the possibility that the unobservables are not time invariant. Kuminoff et al. (2010) show that when the omitted spatial characteristics are time varying, the bias in the first differenced estimates increases substantially. Since not all properties are sold multiple times, the repeat sales approach leads to much smaller sample sizes. In addition, properties that sell multiple times may be systematically different than properties that only sell once. Properties that turn over multiple times may be repeatedly priced below market value, or more importantly, the local disamenity has an above average effect on those properties. With an extensive list of housing characteristics at the time of all sales, the number of time varying unobservables is smaller than in a number of recent studies.

A second strategy for removing the influences of time invariant unobservables is discussed in detail in Parmeter and Pope (2012) and used in Linden and Rockoff (2008), Muehlenbachs et al. (2012), and Haninger et al. (2012) is difference-in-differences. A difficulty that arises when using difference-in-differences in a hedonic property value model is defining the treatment and control groups. To determine the distance at which communication antennas impact nearby property values, the method used in Linden and Rockoff (2008) will be used. Figure 3a illustrates the method used to define treatment and control groups in Linden and Rockoff (2008). The dashed line is the relationship between sales price and distance from a sex offender's property after the sex offender arrives. Sales price is increasing with distance until about 0.1 miles and then flattens out. The solid line is the relationship between sale price and distance from a sex offender's property before the sex offender arrives. Sales price is decreasing with distance until about 0.1 miles and then flattens out. Since the prices of homes are similar between 0.1 and 0.3 miles from an offender's location, properties within that distance are in the control group and properties within 0.1 mile of a sex offender's location are in the treatment group. Figure 3b shows the relationship between sales price and days relative to a sex offender's arrival. For properties in the treatment group, there is a significant decrease in property values after the sex offender's arrival. Properties within 0.1 and 0.3 miles of a sex offender's location remained relatively steady post arrival suggesting properties within that distance can indeed be considered "untreated."

Once the treatment and control groups have been defined, the following regression will be estimated:

$$\ln P_{ijt} = \pi_1 D^1_{ijt} + \pi_2 Post_{ijt} + \pi_3 D^1_{ijt} \cdot Post_{ijt} + x_{ijt}\delta_t + \lambda_t + \gamma_j + \epsilon_{ijt} \tag{4}$$

where $D^1_{ijt}$ is a dummy variable equal to 1 if the property is located in close enough to an antenna site to be in the treatment group, $Post_{ijt}$ is a dummy variable equal to one if the property sold after the nearest antenna was constructed. $\pi_3$ is the parameter of interest. $x_{ijt}$ contains an extensive set of housing characteristics, $\lambda_t$ are year-month dummy variables, and $\gamma_j$ are spatial fixed effects. Notice that this specification allows the equilibrium price function for the housing characteristics to vary over time. This is the specification shown to produce the smallest amount of bias in mean willingness to pay in Kuminoff et al. (2010). Since house prices in the study area appear to be relatively stable over time, a separate regression assumes $\delta_t = \delta$ for all $t$ will be estimated.

# 5 Results

## 5.1 Cross-Section Results

Results for the first specification that uses a continuous measure of distance to the nearest antenna are shown in Table 6. The first two columns do not include any spatial fixed effects to control for time-invariant unobservables that may be correlated with proximity to an antenna. Without these spatial fixed effects, the estimates in Columns 1 and 2 suggest that houses located adjacent to a communication antenna sell for more than a comparable house further away from an antenna. This result is opposite of what is expected. Column 3 includes census tract fixed effects and the results show that holding constant the characteristics of the house, the time the property was sold, and the area in which the property is located, consumers are willing to pay a premium to be located further away from a communication antenna[17]. Unobservables that are correlated with distance to a communication antenna are likely biasing the estimates in Columns 1 and 2. The estimates in Column 3 show that the sales price of a house is increasing at a rate of approximately 0.98% at a distance of 1,000 feet, and at a rate of about 0.88% at 2,500 feet[18]. No effect is found beyond 16,050 feet (approximately 3 miles). Column 4 includes census block-group fixed effects which are more precise rather than the census tract fixed effects used in Column 3. These estimates suggest that the sales price of a house increases at a rate of about 0.83% at a distance of 1,000 feet, and a rate of 0.75% at 2,500 feet. No effect is found beyond 15,540 feet (approximately 2.9 miles). Even though the effect of distance is identified by variation in distance within a smaller geographic area, the specification using census block group fixed effects provides

[17]The results in Table A2 show that when census tract fixed effects are included, the coefficients on the structural housing and neighborhood characteristics change indicating they are also correlated with unobservables at the census tract level.

[18]Using the quadratic of distance, the change in expected sales price with respect to distance is $\hat{\beta}_1 + 2 \cdot \hat{\beta}_2 \cdot D$, where $D$ is distance to the nearest antenna in thousands of feet.

estimates that are smaller and more precisely estimated than the census block specification. This provides further evidence that there are spatially correlated unobservables that are negatively correlated with distance to a communication antenna[19].

The results from the specification that uses the inverse of distance to the nearest antenna are shown in Table 7. As in Table 6, the first two columns do not include spatial fixed effects and the coefficients on the inverse of distance indicate that houses near antennas sell for more than houses further away. Once again, Column 3 shows that the census tract fixed effects are absorbing the effect of time invariant unobservables that are correlated with distance to an antenna, and the coefficient on the inverse of distance now has the expected sign. These estimates show that the sales price of a house is increasing at a rate of approximately 3.6% at a distance of 1,000, feet, and at a rate of about 0.57% at 2,500 feet[20]. When census block-group fixed effects are included (Column 4), the estimates show that the sales price of a house is increasing at a rate of about 2.8% at a distance of 1,000 feet, and a rate of 0.45% at 2,500 feet. Since the derivative with respect to distance is never zero for the inverse of distance, the distance at which sales prices are increasing at a rate of 0.01% was found using the estimates from Column 4 in Tables 6 and 7. This distance is equal to 15,366 feet (2.9 miles) for the quadratic specification and 16,850 feet (3.2 miles) for the inverse of distance.

Overall, the results do not appear to be extremely sensitive to functional form when using a continuous measure of distance, but there are some differences. The inverse distance shows the effect declining more with distance and a greater effect for houses closer to an antenna. When using the inverse of distance, the partial derivative of the hedonic price function with respect to

[19]Regressions were estimated that included the percentage of rural residents in a census tract instead of census tract fixed effects. The results show that the sales price of a house is decreasing as the number of people living in rural areas increases, and that proximity to a communication antenna has a positive effect on the sales price of a house in highly urban areas, and a negative effect in more rural areas. This is consistent with the idea that antennas in more urban areas are more likely to be disguised than in rural areas where the antennas structures tend to be much larger. Urban areas have multiple structures such as tall buildings, smoke stacks, clocks, and church steeples that antennas can be located on or around. The $R^2$ for the urban/rural specification was 0.72 compared to 0.85 in the census tract specification in Table 6.

[20]Using the inverse of distance, the change in expected sales price with respect to distance is $-\hat{\beta}/D^2$.

distance is 0.0284/Distance$^2$ in the census block group specification. In the limit, this is equal to infinity as distance goes to zero, and equals zero as distance goes to infinity. At the median value of 4,500 feet, the inverse distance specification shows that the sales price of a house is increasing at a rate of 0.14% and at a rate of 0.6% using the quadratic specification. The distances at which the sales prices are increasing at the same rate for the two specifications are 1,905 and 15,330 feet. It is reassuring that the latter distance is only 210 feet short of the distance at which no sales price effect is found using the quadratic specification.

The results in Table 8 estimate the same quadratic specification that was used in Table 6, but the sample is restricted to only include the tower-type antenna structures. These structures are larger and are visible at greater distances than the smaller antenna structures and are expected to have a larger effect on property values and have an effect at greater distances. Columns 1 and 2 do not include spatial fixed effects and again indicate that houses in close proximity to an antenna sell for more than a comparable house further away. Once census tract fixed effects are included (Column 3), the estimates have the expected sign and indicate that the tower-type structures do in fact have a larger effect on property values and have an effect further away. Sales prices are increasing at a rate of 1.1% (up from 0.98%) at 1,000 feet, and a rate of 1.1% (up from 0.88%) at 2,500 feet. No effect is found beyond 16,667 feet (3.16 miles). Column 4 includes census block-group fixed effects and once again the effect of distance to a tower on property values is estimated more precisely than in the census tract specification. With this specification, sales prices are increasing at a rate of 1% (up from 0.83%) at 1,000 feet and 0.92% (up from 0.75%) at 2,500 feet. No effect is found beyond 16,269 feet (3.08 miles). While the effects are not extremely different, the estimates are larger when the sample is reduced to only tower-type structures. This provides additional confidence that the proximity measures being used are capturing the visual disamenity associated with communication antennas[21].

[21] Each specification discussed below is also estimated using only tower-type antenna structures. To save space, the results for these specifications are given in the appendix. In general, the estimates using only the tower-type antenna structures show a larger effect and have an effect at greater distances.

The estimates in Tables 9 and 10 use 300 foot distance bands to measure either the effect of having an antenna located within a specified radius from the house (Table 9) or the marginal effect of an additional tower within the same radius (Table 10). The summary statistics in Table 3 show that there are only 127 houses whose nearest antennas is less than 300 feet away so the 0 to 300 foot and 300 to 600 foot distance bands were combined to ensure there is enough variation to identify the effect of distance for houses located closest to an antenna. The estimates in Columns 1 and 2 in Tables 9 and 10 do not include spatial fixed effects and indicate houses near antennas sell for more than houses further away. Row 1 of Columns 1 and 2 suggest that houses within 600 feet of an antenna sell for 13-14% more than a house more than 4,500 feet from an antenna (Table 9) and that an additional antenna within 600 feet leads to an additional 9 to 10% increase in sales price (Table 10). Again, when census tract fixed effects are included, the estimates have the expected sign and suggest that a house located within 600 feet of an antenna sell for 6.3% less than a comparable house more than 4,500 feet from the nearest antenna, and an additional antenna leads to a 3.8% reduction in sales price[22]. When census block-group fixed effects are included, the effect of having an antenna within 600 feet of a property falls to a 5.7% reduction in sales price with an additional antenna leading to a 3.1% reduction. In both specifications, the effect of communication antennas on property values diminishes with distance[23].

The results in Tables 9 and 10 are consistent with the argument made in Mastromonaco (2011)

[22] In the specification that uses a quadratic in distance, the sales price is increasing at a rate of 0.6% at 4,500 feet. If correct, the results using the 300 foot distance rings with more than 4,500 feet from a property is the base category, the reduction in sales price is underestimated.

[23] Bond and Wang (2005) and Bond (2007a) are two similar studies that measure the impact of cell phone towers on property values in New Zealand, but the studies have limitations. The first lacked precise location information for the houses and used street name fixed effects as a proxy for distance to a tower. The second geocodes houses, but the model is misspecified. They use a continuous distance measure but set distance equal to zero if the house sold before the tower was constructed. Bond (2007b) is the only study found that uses U.S. data. It is limited to sales from one area of Orange County Florida and includes the latitude and longitude of each property in each regression. Banfi et al. (2008) looks at the impact of cell phone towers on rents in Zurich Switzerland and finds a significant decrease in rents of about 1.5% on average. Filippova and Rehm (2011) is the most recent study. They use data from the Auckland region of New Zealand and also use distance bands and a continuous distance measure. Their distance band specification yields insignificant results, and the coefficient on the continuous distance measure has a significant, but wronged signed coefficient. They report a negative but insignificant impact on property values. The authors failed to consider the interaction terms between distance and their location variables. Given they used 50 meter increments for their distance bands, it is likely there was not enough variation within each band to identify any impact.

that only considering distance to the nearest site will lead to biased estimates if there are multiple sites that could adversely affect a property's sale price. As is expected, adding an additional antenna near a residential property has a smaller effect than an antenna being located near a property that did not previously have one nearby. Since every coefficient in Columns 3 and 4 of Table 9 is larger than the corresponding coefficient in Columns 3 and 4 of Table 10, the estimates that measure proximity with distance to the nearest site are likely biased. To address this concern, the results in Table 11 use the same quadradic measure of distance to the nearest antenna that was used Table 6 but include the number of antennas near a property using the 300 foot distance bands from Table 10. As expected, the results suggest that only considering proximity to the nearest antenna is biased if there are multiple antennas that could be affecting the property's sale price. The results from Column 4 of in Table 11 show that holding constant the number of nearby antennas, the sales price of a house is increasing at a rate of 0.19% at a distance of 1,000 feet from an antenna, and at a rate of 0.16% at 2,500 feet from an antenna. These estimates are significantly smaller than those in Table 6 that only considered distance to the nearest antenna.

### 5.2 Panel Results

Results from the first repeat sales specification that assumes the structural housing characteristics are constant over time are shown in Table 12. In this specification, the change in sales price is assumed to be a function of the change in distance to the nearest antenna and a set of year dummy variables that are equal to -1 if the year indicates the time of the first sale, 1 if the year indicates the year of the last sale, and 0 for all other sales. Comparing the change in sales price for houses that are sold more than once eliminates any bias that could be caused by time-invariant spatially correlated unobservables. Comparing Columns 3 and 4 for each cross-section specification in Tables 6-11 shows that as more precise spatial fixed effects are used, the estimated effect of communication antennas on the sales price of a house is smaller and more precisely estimated. This indicates that the spatially correlated unobservables are negatively correlated with proximity to an antenna. If this is true, and the unobservables are time invariant, the repeat sales estimates of the impact communication antennas have on property values should be similar to the estimates using the more precise census block group fixed effects.

The results in each column of Table 12 are consistent with this hypothesis. Column 1 includes all houses that sold more than once during the sample period. For every 1,000 foot change in distance to the nearest antenna, on average, the sales price if a house increases by 0.75%. This estimate is similar the rate at which sales prices are increasing in Table 6 at a distance of 1,000 feet (0.83%). Columns 2 and 3 included houses that are sold four or fewer times and three or fewer times, respectively. Both provide estimates similar to Column 1 where all repeat sales are included. Column 4 includes the set of houses that are sold only twice during the 12 years the data cover. Since repeat sales are identified by the standardized address provided by the Mapquest scraping program, limiting the sample to houses that sale only two times reduces the chance of including houses that are being considered repeat sales due to a coding error. Even though the sample size is reduced by 8,910 observations compared to the sample of all repeat sales, the $R^2$ increases by 3.2 points, and the effect of distance is still precisely estimated. In this specification, for every 1,000 foot change in distance to the nearest antenna, on average, the sales price if a house increases by 0.33%. This is slightly smaller than the estimate in Column 4 of Table 11 that holds the number of antennas near a house constant when estimating the effect of proximity of an antenna, but much smaller than the estimates in Column 4 of Tables 9 and 10 that used the 300 foot distance bands.

The repeat sales results in Table 13 are based on relaxing the assumption that structural housing characteristics are constant over time. As is expected, including the changes in structural housing characteristics leads to a higher $R^2$, increases in each characteristic lead to a larger positive change in sales price, and the effect of distance is more precisely estimated. This result suggests that the change in distance to the nearest antenna between sales of the same property is not completely orthogonal to the change in housing characteristics, an assumption that must be made when detailed sales data is not used. Again, Columns 1 through 3 include all repeat sales, houses that sell four or fewer times, or houses that sell three or fewer times. These results show a slightly smaller effect than the results shown in Table 12. However, when the sample is reduced to houses that only sell twice during the sample period, the estimated impact is slightly larger than the estimate in Table 12. In this specification, for every 1,000 foot change in distance to the nearest antenna, on average, the sales price of a house increase by 0.39% compared to 0.33% when the structural characteristics are assumed to be constant. While these estimates are not statistically different at conventional levels[24], a larger effect when the changing structural housing characteristics are included is consistent with the results from Bajari et al. (2012) that show ignoring time-varying correlated unobservables leads to underestimates of the benefits of pollution reduction.

The method used for determining the treatment and control groups for the difference-in-differences specification is shown in Figure 4. The solid line shows the relationship between the sales price of a house and distance to the nearest antenna that was standing at the time it was sold. Sales prices are increasing until about 2,000 feet and then flatten out. The dashed line shows the relationship between the sales price of a house and distance to the nearest site where an antenna will be located. Sales prices are decreasing with distance from the site where an antenna will be located and flatten out at about 2,000 feet. Since 2,000 feet is the point at which the sales price is not affected by an antenna that is standing, or the site where an antenna will be located, houses within 2,000 feet of an antenna site are considered “treated" and those beyond are in the control group.

Estimates from the difference-in-differences specification are shown in Table 14. Column 1 says that holding constant the structural characteristics and the time of sale, houses within 2,000 feet of where an antenna is located or will be located sell for 2.9% more on average than a comparable house more than 2,000 feet of an antenna site. Holding constant the areas in which houses are located, Column 2 shows that a house within 2,000 feet of an antenna site sells for about 1% less than a comparable house more than 2,000 feet away. This result is consistent with all of the

[24] P-value from a Chow test=0.12.

results above and reinforces the importance of including the spatial fixed effects to capture the effect of spatially correlated unobservables. Column 3 reports results from a typical difference-in-difference specification. Houses that are within 2,000 feet of an antenna at the time they were sold sell for about 3.3% less than a comparable house more than 2,000 feet away from an antenna at the time it was sold. The results in Column 4 are from a specification that allows the equilibrium price function with respect to structural housing characteristics change over time and also includes spatial fixed effects. Kuminoff et al. (2010) recommend this specification for estimating willingness to pay when using panel data. The results from this specification show an effect of about 2.2% that is estimated more precisely than in the specification that does not allow the equilibrium price function to change over time, however, the effect is not significantly different from zero at conventional levels.

## 6 Discussion and Conclusions

Overall, the results from the preferred specifications show that houses located near communication antennas sell for less on average than comparable houses located further away from an antenna. There are a few important points to note about these results. First, regardless of the specification, time-invariant spatially correlated unobservables biased the cross-sectional estimates of the reduction in sales price caused by nearby communication antennas when no controls for neighborhood characteristics are included. Columns 1 and 2 in Tables 6-11 do not include any spatial fixed effects and all show that houses near a communication antenna sells for more than a similar house further away from an antenna. Following the recommendation from Kuminoff et al. (2010), Columns 3 and 4 of Tables 6-11 include spatial fixed effects to capture the effect of time invariant spatially correlated unobservables. Once included, each of the three proximity measures used indicated that houses near communication antennas sell for less than a similar house located further away from an antenna. When the more precise census block group fixed effects are included, the estimated reduction in sales price caused by a communication antenna becomes smaller and is estimated more precisely in each of the cross-section specifications. This effect reinforces the importance of the carefully controlling for spatial correlated unobservables that are correlated with proximity to a localized disamentiy.

The results also show that when using a continuous measure of distance, the results are robust to functional form. When the quadratic specification is used, the sales price of a house is increasing at a rate of 0.75% at a distance of 2,500 feet from an antenna, and at a rate of 0.57% at 2,500 feet using the inverse of distance. At an average sales price of $183,619, this amounts to a difference of $275. Even though the differences are small, the results from the continuous specifications also provide evidence that the proximity measures are capturing the visual disamenity associated with communication antennas. Comparing the results in Column 4 of Table 6 to the results in Column 4 in Table 8, the bigger tower-type structures have a larger effect on the sales price of a house and have an effect further away. Using all antennas, the sales price of a house is increasing at a rate of 0.75% at 2,500 feet from an antenna, and the sales price of a house is increasing at a rate of 0.92% at the same distance from a tower-type antenna, a difference of $312.

Consistent with the conjecture made by Mastromonaco (2011), estimating the effect of communication antennas on property values using distance to the nearest antenna is likely biased due to the presence of multiple nearby antennas. The results in Column 4 of Table 9 say that a house located within 600 feet of an antenna sells for 5.7% ($10,466) less than a similar house more than 4,500 feet away from its nearest antenna. The results in Column 4 of Table 10 show that adding an additional antenna within 600 feet of a house leads to a reduction in sales price of 3.1% ($5,692). Since houses are being affected by multiple nearby antennas, Table 11 uses the same quadratic specification from Table 6 but includes the number of antennas located near each house using the same distance bands that were used in Table 10. Holding constant the number of communication antennas near a property, the sales price increasing at a rate of 0.19% at a distance of 1,000 feet compared to a rate of 0.83% at 1,000 feet when only the nearest antenna is considered. Using the average sales price of $183, 619, this is a difference of $1,175.

The results suggest that the omitted spatial characteristics that are correlated with proximity to a communication are time invariant and are being captured by the census block group fixed effects. First, the effect communication antennas have on nearby properties is smaller and is estimated more precisely when census block group fixed effects are used compared to the census tract estimates. This confirms that there are unobservables that are spatially correlated with distance to a communication antenna. Second, the repeat sales method eliminates any bias caused by time-invariant unobservables and provides results very similar to the cross sectional estimates that include census block group fixed effects. This can be seen by comparing the results in Column 4 of Table 11 to the results in Column 4 of Table 13. Using the continuous measure of distance, Table 11 shows that the sales price of a house is increasing at a rate of 0.19% at a distance of 1,000 feet from an antenna, and Table 13 show that for every 1,000 foot change in distance to the nearest antenna, the sales price increases by 0.39%. Using the average sales price of $183,619, this amounts to a difference of $367.

Kuminoff et al. (2010) recommend using difference-in-differences to estimate marginal willingness to pay for localized (dis)amenities when panel data is available. They suggest including spatial fixed effects to capture the effect of time-invariant spatially correlated unobservables, and interacting time dummy variables with the housing characteristics to allow the equilibrium price function to vary over time. Table 14 shows the results from this specification. The estimates in Column 3 are from the typical difference-in-difference specification that assumes the equilibrium price function is constant over time and show that houses within 2,000 feet of a standing antenna sell for 3.3% ($6,059) less than a similar house more than 2,000 feet away from antenna. In the more flexible specification that allows the equilibrium price function to change over time, the 2.2% ($4,040) effect is estimated more precisely, but is not statistically different from zero at conventional levels.

It is not surprising that the difference-in-differences specification does not produce results similar to the repeat sales estimates or the cross-section estimates that include census block group fixed effects. The primary reason is that the presence of multiple antennas near a property makes defining the treatment and control groups difficult. To define the treatment and control groups, the distance from each house to a site where an antenna is standing or will be standing is determined. This distance may identify distance to a site where an antenna will be located, but will ignore the already standing antenna that is just beyond that site. The summary statistics in Table 3 show that this is a relevant concern. There are 804 houses that are located within 2,100 feet of at least two antennas when they sold. Since the distance to a site where an antenna will be located will be highly correlated with distance to the nearest standing antenna for a lot of the houses in the sample, identifying the treatment and control groups using the method from Linden and Rockoff (2008) is not likely to be effective. While the difference-in-differences specification has become increasing popular in the recent literature, the nature of the disamenity evaluated here does not appear meet the criteria necessary to successfully implement this quasi-experimental technique.

The best estimate of reduction in sales price caused by communication antennas shows that the sales price of a house is increasing at a rate of about 0.19% ($348) at a distance of 1,000 feet from the nearest antenna (Table 11 Column 4). This suggests that a property that has an antenna located within 1,000 feet at the time of sale will sell for 0.54% ($992) less than a similar house that is 4,500 feet from the nearest antenna. Comparing this to the specifications that did not control for spatially correlated unobservables demonstrates the importance of including spatial fixed effects in the cross section specifications. In this specification (Table 11 Column 2) the estimates show that the sales price of a house is decreasing, not increasing, at a rate of 0.16% at a distance of 1,000 feet. This suggests that within 1,000 feet of the nearest antenna will sell for 0.70% ($1,285) more than a similar houses that is 4,500 feet from the nearest antenna.

This effect is smaller than the estimated reduction caused by similar disamenities. Kroll and Priestley (1992) provide a review of the literature concerning overhead transmission lines and property values through the early 1990s. They find that in studies where a significant decrease was found, the decrease in property values typically falls in the range of 2% to 10%, and the effect diminishes beyond a few hundred feet. Hamilton and Schwann (1995) estimate the impact of high voltage electric transmission lines have on property values, but primarily focus on the importance of using the correct functional form. They find that properties that are adjacent to a line lose about 6.3% of their value, but more distant properties are hardly affected. Using a repeat sales model, Heintzelman and Tuttle (2012) find that having a wind turbine located 0.5 miles away leads to a reduction in sales price from 8.8-15.81%.

When the sample is restricted to include only tower-type antenna structures, the results show that a house 1,000 feet away from the nearest antenna will sell for 0.73% ($1,340) less than a similar house that is 4,500 feet away. In this sample, there are 2,313 houses within 1,000 feet of a tower-type structure. If for each of these houses the nearest tower-type structure was moved to a distance of 4,500 feet, there would be an aggregate increase in sales price would be equal to $3.1 million. This value should be compared to the cost of camouflaging or disguising communication antennas near residential properties to mitigate the effect they have on property values.

In areas where antennas are highly visable (Figure 1a), there is a potential externality caused by these antennas. If antennas are constructed near residential properties *after* the homeowner purchases the property, they suffer a small but non-trivial decrease in their property value and are unlikely to be compensated by the land owner where the antenna is located or the owner of the antenna. “Camouflaging" is one solution to this problem that has been implemented in some areas. Camouflaged towers blend in with the landscape or are constructed in already standing structures such as church steeples and clock towers. Such developments will change the disamenity associated with communication antennas.

## 7 Tables and Figures

Table 1: Summary Statistics for Structural Housing Characteristics. Central Kentucky Data, 2000-2011. N=142,164.

| Variable | Mean/Share | Std. Dev. | Min | Max |
|---|---|---|---|---|
| Sales Price (2011 Dollars)[a] | 183,619 | 143,162 | 1,028 | 4,859,483 |
| Bedrooms | 3.241 | 0.785 | 1 | 13 |
| Full Bathrooms | 1.811 | 0.751 | 1 | 9 |
| Partial Bathrooms | 0.368 | 0.522 | 0 | 6 |
| Square Feet of Living Space | 1,655 | 7,181 | 500 | 9,688 |
| Lotsize (Acres) | 0.820 | 40.661 | 0 | 436 |
| Lotsize Missing | 0.047 | 0.211 | 0 | 1 |
| Has $<$ in Lot Dimensions[b] | 0.127 | 0.333 | 0 | 1 |
| Has $>$ in Lot Dimensions[b] | 0.003 | 0.058 | 0 | 1 |
| Age (Years) | 33.154 | 29.074 | 0 | 223 |
| Age Unknown | 0.010 | 0.101 | 0 | 1 |
| Fireplace | 0.479 | 0.500 | 0 | 1 |
| Basement | 0.602 | 0.490 | 0 | 1 |
| Finished Basement | 0.175 | 0.380 | 0 | 1 |
| Central Air | 0.909 | 0.287 | 0 | 1 |
| Brick Exterior | 0.346 | 0.476 | 0 | 1 |
| Vinyl Exterior | 0.162 | 0.369 | 0 | 1 |
| Metal Roof | 0.010 | 0.099 | 0 | 1 |
| Composition Roof | 0.940 | 0.238 | 0 | 1 |
| Ranch Style | 0.447 | 0.497 | 0 | 1 |
| Modular Style | 0.014 | 0.116 | 0 | 1 |
| Cape Cod Style | 0.084 | 0.277 | 0 | 1 |
| Carport | 0.057 | 0.233 | 0 | 1 |
| Garage | 0.663 | 0.473 | 0 | 1 |
| One Car Garage | 0.169 | 0.374 | 0 | 1 |
| Multiple Car Garage | 0.563 | 0.496 | 0 | 1 |
| Within 1 Mile Parkway/Interstate | 0.485 | 0.500 | 0 | 1 |
| Within 1 Mile Railroad | 0.511 | 0.500 | 0 | 1 |
| Within 1 Mile Ft. Knox | 0.014 | 0.116 | 0 | 1 |

[a] Sales prices were converted to 2011 dollars using the CPI.
[b] The lot dimensions indicated the lot size was less (greater) than the listed size.

Table 2: Averages and Test for Differences in Means for Houses Within and Beyond 4,500 Feet of an Antenna. Central Kentucky Data, 2000-2011.

| | Mean/Share | | |
|---|---|---|---|
| Variable | <4,500 Feet | >4,500 Feet | Test Statistic |
| Sales Price (2011 Dollars) | 167,247 | 200,226 | 43.61 |
| Bedrooms | 3.161 | 3.323 | 39.00 |
| Full Bathrooms | 1.687 | 1.937 | 63.66 |
| Partial Bathrooms | 0.347 | 0.390 | 15.83 |
| Square Feet of Living Space | 1,573 | 1,739 | 43.70 |
| Lotsize (Acres) | 0.383 | 1.263 | 35.52 |
| Lotsize Missing | 0.044 | 0.049 | 3.96 |
| Has < in Lot Dimensions | 0.149 | 0.105 | -24.96 |
| Has > in Lot Dimensions | 0.003 | 0.004 | 2.81 |
| Age (Years) | 42.078 | 24.096 | -122.86 |
| Age Unknown | 0.006 | 0.014 | 14.65 |
| Fireplace | 0.474 | 0.485 | 4.09 |
| Basement | 0.613 | 0.590 | -8.96 |
| Finished Basement | 0.153 | 0.197 | 21.80 |
| Central Air | 0.898 | 0.921 | 15.050 |
| Brick Exterior | 0.322 | 0.370 | 18.89 |
| Vinyl Exterior | 0.157 | 0.168 | 5.69 |
| Metal Roof | 0.006 | 0.013 | 13.16 |
| Composition Roof | 0.944 | 0.936 | -6.90 |
| Ranch Style | 0.409 | 0.485 | 29.19 |
| Modular Style | 0.004 | 0.024 | 31.68 |
| Cape Cod Style | 0.102 | 0.066 | -24.23 |
| Carport | 0.066 | 0.049 | -13.44 |
| Garage | 0.657 | 0.668 | 4.34 |
| One Car Garage | 0.209 | 0.128 | -41.29 |
| Multiple Car Garage | 0.494 | 0.632 | 53.00 |
| Within 1 Mile Parkway/Interstate | 0.629 | 0.338 | -114.93 |
| Within 1 Mile Railroad | 0.569 | 0.452 | -44.19 |
| Within 1 Mile Ft. Knox | 0.014 | 0.014 | -0.560 |
| Sample Size | 71,604 | 70,560 | |

[a] Sales prices were converted to 2011 dollars using the CPI.

[b] The lot dimensions indicated the lot size was less (greater) than the listed size.

Table 3: Summary Statistics for the Communication Antenna Proximity Measures. Central Kentucky Data, 2000-2011. N=142,164.

| Continuous | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|
| Distance to Closest Standing Antenna When Sold (feet)[a] | 5,794 | 4,703 | 59 | 51,663 |

| Equal to 1 if Within | Share | Number |
|---|---|---|
| Distance0to300 | 0.001 | 127 |
| Distance300to600 | 0.005 | 752 |
| Distance600to900 | 0.010 | 1,467 |
| Distance900to1200 | 0.017 | 2,458 |
| Distance1200to1500 | 0.026 | 3,641 |
| Distance1500to1800 | 0.031 | 4,350 |
| Distance1800to2100 | 0.034 | 4,831 |
| Distance2100to2400 | 0.041 | 5,832 |
| Distance2400to2700 | 0.044 | 6,262 |
| Distance2700to3000 | 0.049 | 6,959 |
| Distance3000to3300 | 0.050 | 7,128 |
| Distance3300to3600 | 0.050 | 7,055 |
| Distance3600to3900 | 0.051 | 7,193 |
| Distance3900to4200 | 0.049 | 7,018 |
| Distance4200to4500 | 0.046 | 6,531 |

| Number Within | # Equal to 1 | # Equal to 2 | # Equal to 3 |
|---|---|---|---|
| Count0to300 | 122 | 5 | 0 |
| Count300to600 | 733 | 23 | 0 |
| Count600to900 | 1,471 | 54 | 0 |
| Count900to1200 | 2,473 | 80 | 0 |
| Count1200to1500 | 3,744 | 148 | 3 |
| Count1500to1800 | 4,620 | 204 | 9 |
| Count1800to2100 | 5,538 | 290 | 2 |
| Count2100to2400 | 6,829 | 365 | 12 |
| Count2400to2700 | 7,764 | 475 | 22 |
| Count2700to3000 | 8,965 | 690 | 10 |
| Count3000to3300 | 10,031 | 757 | 48 |
| Count3300to3600 | 10,580 | 848 | 62 |
| Count3600to3900 | 11,595 | 1043 | 109 |
| Count3900to4200 | 12,898 | 1268 | 128 |
| Count4200to4500 | 13,511 | 1364 | 128 |

[a] Distance in thousands of feet is used in the analysis that follows.

Table 4: Changes in Census Tract Demographics from 2000 to 2010. 322 Census Tracts in Central Kentucky.

| | U.S. Mean | | | Sample Mean | | |
|---|---|---|---|---|---|---|
| Variable | 2000 | 2010 | % Change | 2000 | 2010 | % Change |
| Mean Income[a] | 71,728 | 70,883 | -1.18 | 63,924 | 60,290 | -6.00 |
| Median Income[a] | 53,176 | 51,914 | -2.37 | 51,805 | 48,649 | -6.00 |
| % Unemployed | 3.70 | 7.90 | 113.51 | 5.24 | 8.49 | 62.00 |
| % No High School Diploma | 12.10 | 8.70 | -28.10 | 13.91 | 10.41 | -25.00 |
| % High School Diploma | 28.60 | 29.00 | 1.40 | 34.43 | 35.36 | 3.00 |
| % Bachelors Degree or Higher | 24.40 | 27.90 | 14.34 | 17.38 | 20.46 | 18.00 |
| % Black | 12.00 | 12.00 | 0.00 | 9.01 | 9.62 | 7.00 |
| % White | 75.00 | 74.00 | -1.33 | 88.21 | 86.66 | -2.00 |
| % Owns Home | 66.00 | 67.00 | 1.52 | 72.73 | 71.05 | -2.00 |
| % Out of State | 8.40 | 2.40 | -71.00 | 8.13 | 9.12 | 12.00 |

[a] Incomes were converted to 2010 dollars using the CPI.

Table 5: Summary Statistics for Changing House Characteristics for Houses that Sold More Than Once. Central Kentucky Data, 2000-2011. 26,579 Unique Repeat Sales.

| Variable | Number Changed | Percent Changed |
|---|---|---|
| Number of Bedrooms | 4,311 | 17 |
| Number of Full Bathrooms | 2,617 | 10 |
| Number of Partial Bathrooms | 1,486 | 6 |
| Finished Basement | 4,558 | 18 |
| Central Air | 2,783 | 11 |
| Has Garage | 3,097 | 12 |
| Has Carport | 666 | 3 |

Table 6: Cross-Section Regression Results Showing the Effect of All Antennas on Property Values using a Continuous Measure of Distance. Central Kentucky Data, 2000-2011.

| VARIABLES[a] | (1) ln(Sales Price) | (2) ln(Sales Price) | (3) ln(Sales Price) | (4) ln(Sales Price) |
|---|---|---|---|---|
| Distance to Any Antenna | -0.00922*** | -0.0113*** | 0.0104*** | 0.00892*** |
| | (0.000624)[b] | (0.000610) | (0.00195) | (0.00176) |
| Distance$^2$ to Any Antenna | 0.000162*** | 0.000182*** | -0.000324*** | -0.000287*** |
| | (2.34e-05) | (2.28e-05) | (6.18e-05) | (5.81e-05) |
| Constant | 10.37*** | 10.38*** | 10.50*** | 10.23*** |
| | (0.0104) | (0.0204) | (0.0315) | (0.0200) |
| Observations | 142,161 | 142,161 | 142,161 | 142,161 |
| R-squared | 0.703 | 0.718 | 0.853 | 0.862 |
| Year-Month Dummies | No | Yes | Yes | Yes |
| Tract Fixed Effects | No | No | Yes | No |
| Block Group Fixed Effects | No | No | No | Yes |

[a] Also included in each regression are: bedrooms, full bathrooms, partial bathrooms, square feet, square feet$^2$, lot size, lot size missing, age, age$^2$, age unknown, fireplace, basement, finished basement, central air, exterior type, roof type, style of home, garage, carport, 1 mile parkway/interstate, 1 mile rail road, 1 mile Ft. Knox.

[b] Standard errors are clustered at the level of included fixed effects.

*** p<0.01, ** p<0.05, * p<0.1

Table 7: Cross-Section Regression Results Showing the Effect of All Antennas on Property Values using the Inverse of Distance to the Nearest Antenna. Central Kentucky Data, 2000-2011.

| VARIABLES | (1)<br>ln(Sales Price) | (2)<br>ln(Sales Price) | (3)<br>ln(Sales Price) | (4)<br>ln(Sales Price) |
|---|---|---|---|---|
| Inverse Distance to Any Antenna | 0.0805*** | 0.0902*** | -0.0358*** | -0.0284*** |
| | (0.00372) | (0.00364) | (0.00887) | (0.00755) |
| Constant | 10.29*** | 10.28*** | 10.56*** | 10.28*** |
| | (0.00994) | (0.0202) | (0.0302) | (0.0187) |
| Observations | 142,161 | 142,161 | 142,161 | 142,161 |
| R-squared | 0.703 | 0.717 | 0.853 | 0.862 |
| Year-Month Dummies | No | Yes | Yes | Yes |
| Tract Fixed Effects | No | No | Yes | No |
| Block Group Fixed Effects | No | No | No | Yes |

[a] Also included in each regression are: bedrooms, full bathrooms, partial bathrooms, square feet, square feet$^2$, lot size, lot size missing, age, age$^2$, age unknown, fireplace, basement, finished basement, central air, exterior type, roof type, style of home, garage, carport, 1 mile parkway/interstate, 1 mile rail road, 1 mile Ft. Knox.

[b] Standard errors are clustered at the level of included fixed effects.

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 8: Cross-Section Regression Results Showing the Effect of Towers Only on Property Values using a Continuous Measure of Distance. Central Kentucky Data, 2000-2011.

| VARIABLES[a] | (1) ln(Sales Price) | (2) ln(Sales Price) | (3) ln(Sales Price) | (4) ln(Sales Price) |
|---|---|---|---|---|
| Distance to Tower | -0.00446*** | -0.00737*** | 0.0119*** | 0.0109*** |
| | (0.000597)[b] | (0.000585) | (0.00213) | (0.00187) |
| Distance$^2$ to Tower | 2.23e-05 | 6.31e-05*** | -0.000357*** | -0.000335*** |
| | (2.24e-05) | (2.19e-05) | (6.54e-05) | (6.04e-05) |
| Constant | 10.34*** | 10.36*** | 10.49*** | 10.22*** |
| | (0.0104) | (0.0204) | (0.0315) | (0.0205) |
| Observations | 142,161 | 142,161 | 142,161 | 142,161 |
| R-squared | 0.702 | 0.717 | 0.853 | 0.862 |
| Year-Month Dummies | No | Yes | Yes | Yes |
| Tract Fixed Effects | No | No | Yes | No |
| Block Group Fixed Effects | No | No | No | Yes |

[a] Also included in each regression are: bedrooms, full bathrooms, partial bathrooms, square feet, square feet$^2$, lot size, lot size missing, age, age$^2$, age unknown, fireplace, basement, finished basement, central air, exterior type, roof type, style of home, garage, carport, 1 mile parkway/interstate, 1 mile rail road, 1 mile Ft. Knox.

[b] Standard errors are clustered at the level of included fixed effects.

*** p<0.01, ** p<0.05, * p<0.1

Table 9: Cross-Section Regression Results Showing the Effect of All Antennas on Property Values Using the Nearest Antenna Method with the Closest Rings Combined. Central Kentucky Sales Data. 2000-2011.

| VARIABLES[a] | (1) ln(Sales Price) | (2) ln(Sales Price) | (3) ln(Sales Price) | (4) ln(Sales Price) |
|---|---|---|---|---|
| Distance0to600 | 0.131*** | 0.140*** | -0.0630*** | -0.0572*** |
| | (0.0136)[b] | (0.0133) | (0.0196) | (0.0178) |
| Distance600to900 | 0.0982*** | 0.111*** | -0.0756*** | -0.0699*** |
| | (0.0106) | (0.0104) | (0.0168) | (0.0152) |
| Distance900to1200 | 0.105*** | 0.121*** | -0.0697*** | -0.0727*** |
| | (0.00829) | (0.00809) | (0.0160) | (0.0141) |
| Distance1200to1500 | 0.110*** | 0.122*** | -0.0509*** | -0.0581*** |
| | (0.00689) | (0.00672) | (0.0119) | (0.0107) |
| Distance1500to1800 | 0.0798*** | 0.0911*** | -0.0600*** | -0.0687*** |
| | (0.00634) | (0.00619) | (0.0114) | (0.0106) |
| Distance1800to2100 | 0.0623*** | 0.0736*** | -0.0516*** | -0.0544*** |
| | (0.00603) | (0.00589) | (0.0113) | (0.0102) |
| Distance2100to2400 | 0.0425*** | 0.0565*** | -0.0511*** | -0.0536*** |
| | (0.00554) | (0.00541) | (0.0114) | (0.00964) |
| Distance2400to2700 | 0.0413*** | 0.0547*** | -0.0476*** | -0.0448*** |
| | (0.00535) | (0.00523) | (0.0106) | (0.00862) |
| Distance2700to3000 | 0.0115** | 0.0239*** | -0.0512*** | -0.0457*** |
| | (0.00510) | (0.00499) | (0.0108) | (0.00849) |
| Distance3000to3300 | 0.00454 | 0.0164*** | -0.0525*** | -0.0489*** |
| | (0.00504) | (0.00492) | (0.00990) | (0.00825) |
| Distance3300to3600 | 0.0232*** | 0.0337*** | -0.0406*** | -0.0360*** |
| | (0.00507) | (0.00495) | (0.00940) | (0.00778) |
| Distance3600to3900 | 0.0130*** | 0.0230*** | -0.0419*** | -0.0356*** |
| | (0.00501) | (0.00489) | (0.00918) | (0.00712) |
| Distance3900to4200 | 0.0239*** | 0.0327*** | -0.0275*** | -0.0201*** |
| | (0.00505) | (0.00493) | (0.00837) | (0.00660) |
| Distance4200to4500 | 0.0210*** | 0.0270*** | -0.0168** | -0.00857 |
| | (0.00521) | (0.00509) | (0.00707) | (0.00627) |
| Constant | 10.29*** | 10.28*** | 10.56*** | 10.30*** |
| | (0.00993) | (0.0201) | (0.0295) | (0.0194) |
| Observations | 142,164 | 142,164 | 142,164 | 142,164 |
| R-squared | 0.703 | 0.718 | 0.853 | 0.862 |
| Year-Month Dummies | No | Yes | Yes | Yes |
| Tract Fixed Effects | No | No | Yes | No |
| Block Group Fixed Effects | No | No | No | Yes |

[a] Also included in each regression are: bedrooms, full bathrooms, partial bathrooms, square feet, square feet$^2$, lot size, lot size missing, age, age$^2$, age unknown, fireplace, basement, finished basement, central air, exterior type, roof type, style of home, garage, carport, 1 mile parkway/interstate, 1 mile rail road, 1 mile Ft. Knox.

[b] Standard errors are clustered at the level of included fixed effects.

*** p<0.01, ** p<0.05, * p<0.1

Table 10: Cross-Section Regression Results Showing the Effect of All Antennas on Property Values Using the Antenna Count Method with the Closest Rings Combined. Central Kentucky Sales Data. 2000-2011.

| VARIABLES[a] | (1) ln(Sales Price) | (2) ln(Sales Price) | (3) ln(Sales Price) | (4) ln(Sales Price) |
|---|---|---|---|---|
| Count0to600 | 0.0993*** | 0.100*** | -0.0384** | -0.0307** |
| | (0.0129)[b] | (0.0126) | (0.0166) | (0.0148) |
| Count600to900 | 0.0636*** | 0.0693*** | -0.0502*** | -0.0458*** |
| | (0.00981) | (0.00957) | (0.0146) | (0.0133) |
| Count900to1200 | 0.0697*** | 0.0784*** | -0.0432*** | -0.0483*** |
| | (0.00766) | (0.00748) | (0.0131) | (0.0118) |
| Count1200to1500 | 0.0732*** | 0.0787*** | -0.0307*** | -0.0371*** |
| | (0.00617) | (0.00602) | (0.00973) | (0.00900) |
| Count1500to1800 | 0.0493*** | 0.0536*** | -0.0397*** | -0.0480*** |
| | (0.00551) | (0.00538) | (0.00810) | (0.00769) |
| Count1800to2100 | 0.0453*** | 0.0494*** | -0.0291*** | -0.0315*** |
| | (0.00502) | (0.00490) | (0.00795) | (0.00719) |
| Count2100to2400 | 0.0299*** | 0.0363*** | -0.0264*** | -0.0303*** |
| | (0.00451) | (0.00440) | (0.00870) | (0.00702) |
| Count2400to2700 | 0.0305*** | 0.0362*** | -0.0289*** | -0.0277*** |
| | (0.00418) | (0.00408) | (0.00706) | (0.00635) |
| Count2700to3000 | 0.00339 | 0.00958** | -0.0307*** | -0.0286*** |
| | (0.00385) | (0.00376) | (0.00739) | (0.00608) |
| Count3000to3300 | 0.00398 | 0.00951*** | -0.0299*** | -0.0311*** |
| | (0.00362) | (0.00353) | (0.00694) | (0.00557) |
| Count3300to3600 | 0.0167*** | 0.0213*** | -0.0251*** | -0.0239*** |
| | (0.00349) | (0.00340) | (0.00608) | (0.00482) |
| Count3600to3900 | 0.00973*** | 0.0147*** | -0.0291*** | -0.0274*** |
| | (0.00323) | (0.00315) | (0.00626) | (0.00504) |
| Count3900to4200 | 0.0255*** | 0.0304*** | -0.0237*** | -0.0196*** |
| | (0.00306) | (0.00299) | (0.00652) | (0.00465) |
| Count4200to4500 | 0.0215*** | 0.0266*** | -0.0191*** | -0.0140*** |
| | (0.00302) | (0.00295) | (0.00613) | (0.00458) |
| Constant | 10.29*** | 10.29*** | 10.56*** | 10.31*** |
| | (0.00992) | (0.0201) | (0.0294) | (0.0206) |
| Observations | 142,164 | 142,164 | 142,164 | 142,164 |
| R-squared | 0.703 | 0.718 | 0.853 | 0.862 |
| Year-Month Dummies | No | Yes | Yes | Yes |
| Tract Fixed Effects | No | No | Yes | No |
| Block Group Fixed Effects | No | No | No | Yes |

[a] Also included in each regression are: bedrooms, full bathrooms, partial bathrooms, square feet, square feet$^2$, lot size, lot size missing, age, age$^2$, age unknown, fireplace, basement, finished basement, central air, exterior type, roof type, style of home, garage, carport, 1 mile parkway/interstate, 1 mile rail road, 1 mile Ft. Knox.

[b] Standard errors are clustered at the level of included fixed effects.

*** p<0.01, ** p<0.05, * p<0.1

Table 11: Cross-Section Regression Results Showing the Effect of All Antennas on Property Values using a Continuous Measure of Distance with the Density of Nearby Antennas. Central Kentucky Data, 2000-2011.

| VARIABLES | (1) ln(Sales Price) | (2) ln(Sales Price) | (3) ln(Sales Price) | (4) ln(Sales Price) |
|---|---|---|---|---|
| Distance to any Antenna | -0.000204 | -0.00137* | 0.00409* | 0.00212 |
| | (0.000798) | (0.000779) | (0.00216) | (0.00198) |
| Distance$^2$ to any Antenna | -0.000104*** | -0.000109*** | -0.000156** | -0.000103* |
| | (2.75e-05) | (2.69e-05) | (6.20e-05) | (5.97e-05) |
| Constant | 10.31*** | 10.32*** | 10.54*** | 10.31*** |
| | (0.0109) | (0.0206) | (0.0338) | (0.0232) |
| Observations | 142,161 | 142,161 | 142,161 | 142,161 |
| R-squared | 0.704 | 0.719 | 0.853 | 0.862 |
| Year-Month Dummies | No | Yes | Yes | Yes |
| Tract Fixed Effects | No | No | Yes | No |
| Block Group Fixed Effects | No | No | No | Yes |
| Density of Antennas | Yes | Yes | Yes | Yes |
| F Statistic for Joint Significance of Distance | 61.98 | 126 | 3.69 | 2.33 |
| P-value for F | 0 | 0 | .03 | .1 |

[a] Also included in each regression are: bedrooms, full bathrooms, partial bathrooms, square feet, square feet$^2$, lot size, lot size missing, age, age$^2$, age unknown, fireplace, basement, finished basement, central air, exterior type, roof type, style of home, garage, carport, 1 mile parkway/interstate, 1 mile rail road, 1 mile Ft. Knox.

[b] Standard errors are clustered at the level of included fixed effects.

[c] Density is measured as the the number of antennas located within specified distances from the property as in Table 10.

[d] The P-value (0.0001) from a Chow test confirms that the estimates in columns 3 and 4 for distance and distance squared are statistically different.

*** p<0.01, ** p<0.05, * p<0.1

Table 12: Repeat Sales Regression Results Showing the Effect of All Antennas on Property Values Using a Continuous Measure of Distance. Constant Structural Characteristics. Central Kentucky Data, 2000-2011.

| VARIABLES | (1)<br>Δ ln(Sold Price) | (2)<br>Δ ln(Sold Price) | (3)<br>Δ ln(Sold Price) | (4)<br>Δ ln(Sold Price) |
|---|---|---|---|---|
| Δ Distance<br>to any Antenna | 0.00754*** | 0.00748*** | 0.00727*** | 0.00332*** |
| | (0.00103) | (0.00103) | (0.00105) | (0.00111) |
| Constant | 0.0545*** | 0.0553*** | 0.0610*** | 0.151*** |
| | (0.00308) | (0.00311) | (0.00332) | (0.00525) |
| Observations | 29,886 | 29,719 | 28,387 | 20,976 |
| R-squared | 0.102 | 0.103 | 0.107 | 0.144 |
| All Repeats | Yes | No | No | No |
| Four or Less | No | Yes | No | No |
| Three or Less | No | No | Yes | No |
| Sold Twice | No | No | No | Yes |
| F Statistic | 277.55 | 277.36 | 275.47 | 269.17 |

[a] Year dummy variables were also included. The dummy variables are equal to -1 if the year indicates the first sale of the property, 1 if the year indicates the year of the last sale of the property, and 0 otherwise.

[b] Standard errors are clustered at the property level.

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 13: Repeat Sales Regression Results Showing the Effect of All Antennas on Property Values Using a Continuous Measure of Distance. Changing Structural Characteristics. Central Kentucky Data, 2000-2011.

| VARIABLES | (1)<br>Δ ln(Sold Price) | (2)<br>Δ ln(Sold Price) | (3)<br>Δ ln(Sold Price) | (4)<br>Δ ln(Sold Price) |
|---|---|---|---|---|
| Δ Distance to any Antenna | 0.00746*** | 0.00739*** | 0.00722*** | 0.00388*** |
| | (0.000965) | (0.000968) | (0.000987) | (0.00104) |
| Δ Bedrooms | 0.0785*** | 0.0770*** | 0.0740*** | 0.0619*** |
| | (0.00558) | (0.00554) | (0.00557) | (0.00621) |
| Δ Full Bathrooms | 0.170*** | 0.170*** | 0.170*** | 0.168*** |
| | (0.00792) | (0.00795) | (0.00814) | (0.00897) |
| Δ Partial Bathrooms | 0.104*** | 0.104*** | 0.106*** | 0.110*** |
| | (0.00950) | (0.00951) | (0.00979) | (0.0113) |
| Δ Finished Basement | 0.0210*** | 0.0213*** | 0.0210*** | 0.00960** |
| | (0.00383) | (0.00384) | (0.00393) | (0.00455) |
| Δ Central Air | 0.255*** | 0.255*** | 0.251*** | 0.243*** |
| | (0.00974) | (0.00979) | (0.0100) | (0.0116) |
| Δ Carport | 0.0592*** | 0.0600*** | 0.0554*** | 0.0391*** |
| | (0.0144) | (0.0146) | (0.0148) | (0.0150) |
| Δ Garage | 0.0158** | 0.0156** | 0.0136* | 0.0204** |
| | (0.00772) | (0.00775) | (0.00793) | (0.00899) |
| Constant | 0.0354*** | 0.0361*** | 0.0411*** | 0.122*** |
| | (0.00286) | (0.00289) | (0.00309) | (0.00489) |
| Observations | 29,886 | 29,719 | 28,387 | 20,976 |
| R-squared | 0.202 | 0.202 | 0.203 | 0.230 |
| All Repeats | Yes | No | No | No |
| Four or Less | No | Yes | No | No |
| Three or Less | No | No | Yes | No |
| Sold Twice | No | No | No | Yes |
| F Statistic | 273.19 | 272.17 | 263.96 | 231.11 |

[a] Year dummy variables were also included. The dummy variables are equal to -1 if the year indicates the first sale of the property, 1 if the year indicates the year of the last sale of the property, and 0 otherwise.

[b] Standard errors are clustered at the property level.

*** p<0.01, ** p<0.05, * p<0.1

Table 14: Difference-in-Difference Estimates of the Effect of All Antennas on Property Values. Central Kentucky Data, 2000-2011.

| VARIABLES[a] | (1) ln(Sold Price) | (2) ln(Sold Price) | (3) ln(Sold Price) | (4) ln(Sold Price) |
|---|---|---|---|---|
| Within 2000 Feet of an Antenna Site | 0.0289*** | -0.0101*** | 0.0135 | 0.00303 |
| | (0.00294)[b] | (0.00250) | (0.0144) | (0.0133) |
| Antenna Standing When Sold | | | -0.0164** | -0.0206*** |
| | | | (0.00801) | (0.00736) |
| Within 2000 Feet x Antenna Standing When Sold | | | -0.0334** | -0.0221 |
| | | | (0.0152) | (0.0135) |
| Constant | 10.29*** | 10.55*** | 10.56*** | 10.78*** |
| | (0.0202) | (0.0905) | (0.0302) | (0.0324) |
| Observations | 142,164 | 142,164 | 142,164 | 142,164 |
| R-squared | 0.716 | 0.853 | 0.853 | 0.861 |
| Year-Month Dummies | Yes | Yes | Yes | Yes |
| Tract Fixed Effects | No | Yes | Yes | Yes |
| Allows Effect of Housing Characteristics to Vary Over Time[c] | No | No | No | Yes |

[a] Also included in each regression are: bedrooms, full bathrooms, partial bathrooms, square feet, square feet$^2$, lot size, lot size missing, age, age$^2$, age unknown, fireplace, basement, finished basement, central air, exterior type, roof type, style of home, garage, carport, 1 mile parkway/interstate, 1 mile rail road, 1 mile Ft. Knox.

[b] Standard errors are clustered at the level of included fixed effects.

[c] Structural housing characteristics were interacted with time dummy variables.

*** p<0.01, ** p<0.05, * p<0.1

Figure 1a: Houses Likely Affected by Nearby Tower


Figure 1b: Houses Likely Unaffected by Nearby Tower

Figure 2: Four Quarter Percent Change in the FHFA Housing CPI

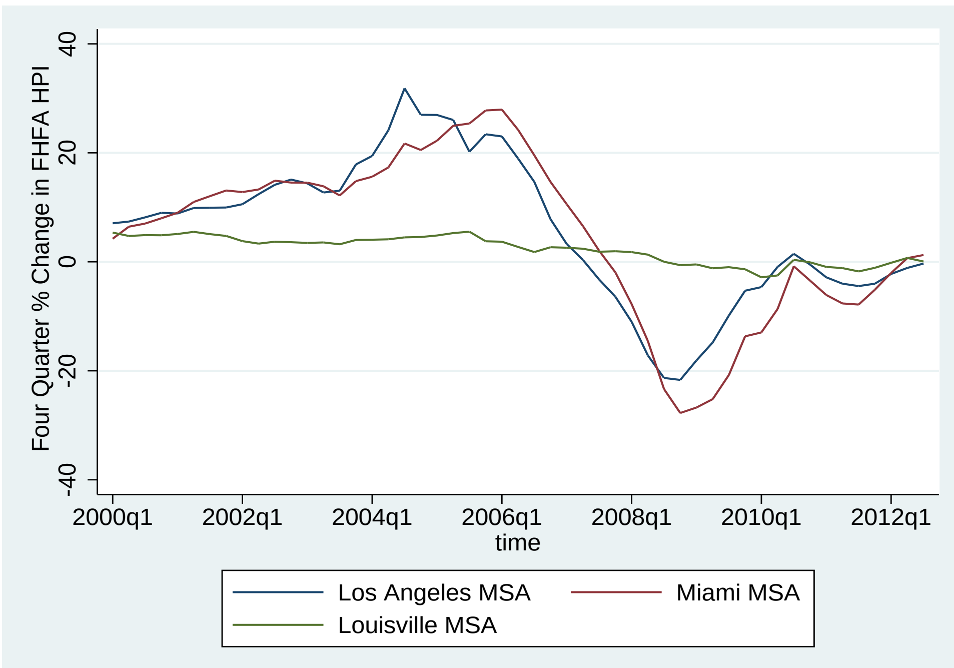


Figure 3a: Figure 2B in Linden and Rockoff (2008)

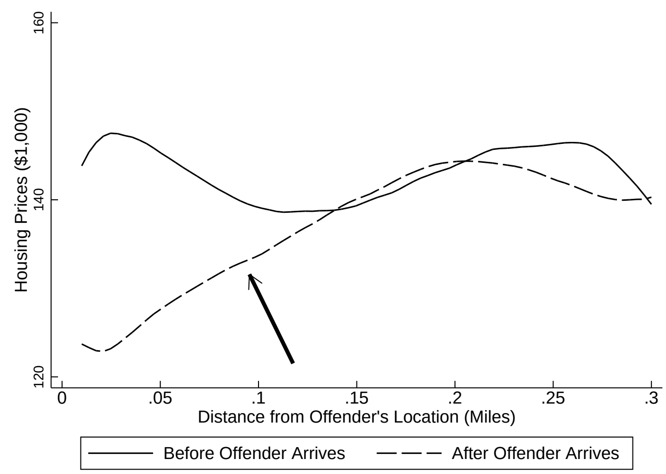



Figure 3b: Figure 3B in Linden and Rockoff (2008)

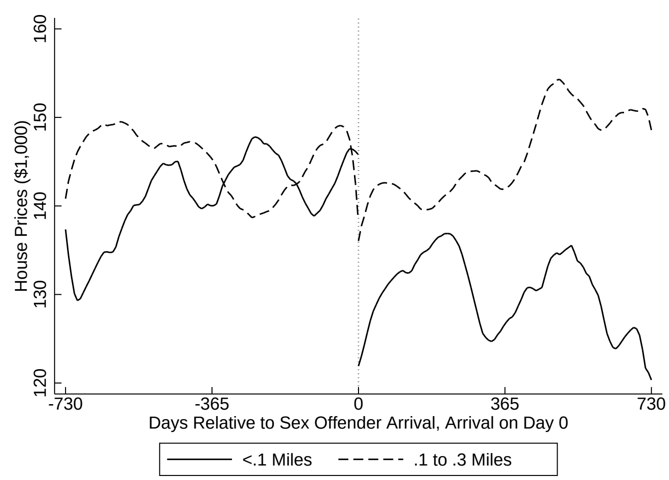
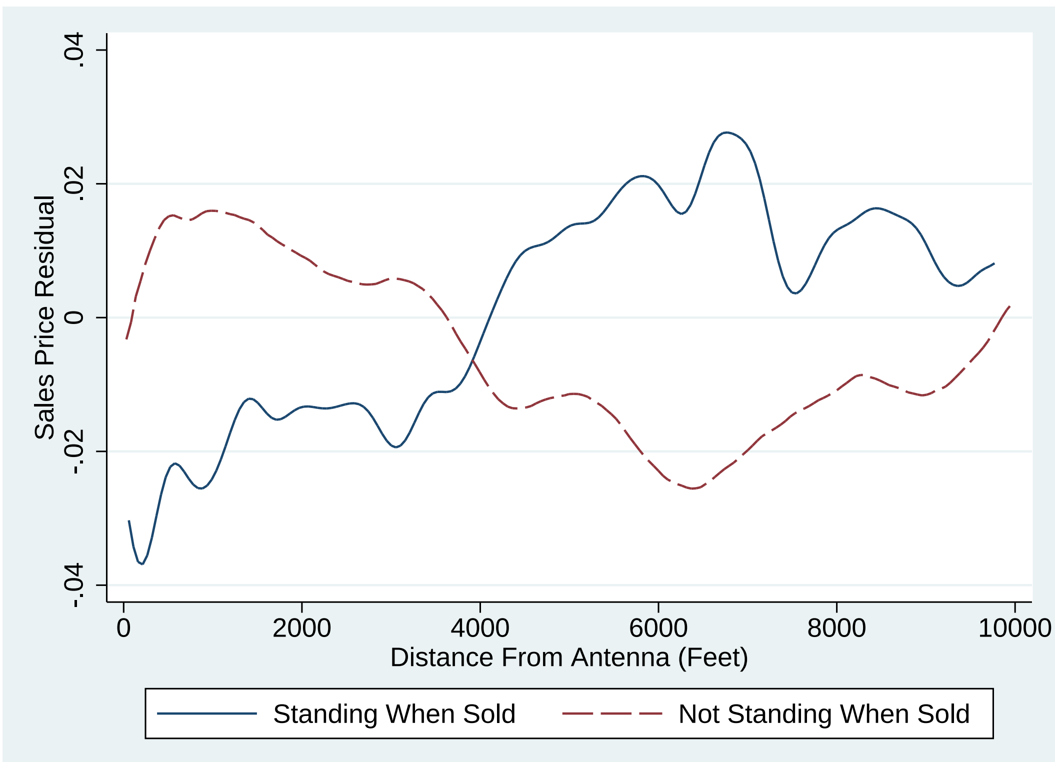


Figure 4: Non-Parametric Plot of the Relationship Between Sales Price and Distance to the Nearest Antenna



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## Appendix

Table A1: Summary Statistics for the Communication Towers Proximity Measures. Central Kentucky Data, 200-2011. N=142,164.

| Continuous | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|
| Distance to Closest Standing Tower When Sold (feet)[a] | 6,353 | 4,800 | 59 | 51,663 |

| Equal to 1 if Within | Share | Number |
|---|---|---|
| TowerDistance0to300 | 0.001 | 93 |
| TowerDistance300to600 | 0.004 | 586 |
| TowerDistance600to900 | 0.008 | 1,128 |
| TowerDistance900to1200 | 0.013 | 1,879 |
| TowerDistance1200to1500 | 0.02 | 2,832 |
| TowerDistance1500to1800 | 0.024 | 3,457 |
| TowerDistance1800to2100 | 0.028 | 3,934 |
| TowerDistance2100to2400 | 0.034 | 4,886 |
| TowerDistance2400to2700 | 0.036 | 5,187 |
| TowerDistance2700to3000 | 0.040 | 5,670 |
| TowerDistance3000to3300 | 0.042 | 5,959 |
| TowerDistance3300to3600 | 0.042 | 6,033 |
| TowerDistance3600to3900 | 0.046 | 6,528 |
| TowerDistance3900to4200 | 0.047 | 6,659 |
| TowerDistance4200to4500 | 0.044 | 6,239 |

| Number Within | # Equal to 1 | # Equal to 2 | # Equal to 3 |
|---|---|---|---|
| TowerCount0to300 | 93 | 0 | 0 |
| TowerCount300to600 | 574 | 13 | 0 |
| TowerCount600to900 | 1,156 | 10 | 0 |
| TowerCount900to1200 | 1,883 | 24 | 0 |
| TowerCount1200to1500 | 2,897 | 38 | 0 |
| TowerCount1500to1800 | 3,559 | 54 | 0 |
| TowerCount1800to2100 | 4,224 | 91 | 0 |
| TowerCount2100to2400 | 5,248 | 153 | 1 |
| TowerCount2400to2700 | 5,903 | 222 | 2 |
| TowerCount2700to3000 | 6,851 | 271 | 1 |
| TowerCount3000to3300 | 7,674 | 319 | 9 |
| TowerCount3300to3600 | 8,043 | 351 | 14 |
| TowerCount3600to3900 | 9,173 | 519 | 44 |
| TowerCount3900to4200 | 10,381 | 586 | 24 |
| TowerCount4200to4500 | 10,694 | 652 | 49 |

[a] Distance in thousands of feet is used in the analysis that follows.

Table A2: Cross-Section Regression Results Showing the Effect of All Antennas on Property Values using a Continuous Measure of Distance. Central Kentucky Data, 2000-2011. All Variables.

| VARIABLES | (1)<br>ln(Sales Price) | (2)<br>ln(Sales Price) | (3)<br>ln(Sales Price) | (4)<br>ln(Sales Price) |
|---|---|---|---|---|
| Distance to any Antenna | -0.00922*** | -0.0113*** | 0.0104*** | 0.00892*** |
| | (0.000624) | (0.000610) | (0.00195) | (0.00176) |
| Distance$^2$ to any Antenna | 0.000162*** | 0.000182*** | -0.000324*** | -0.000287*** |
| | (2.34e-05) | (2.28e-05) | (6.18e-05) | (5.81e-05) |
| Bedrooms | -0.00280 | -0.00508*** | 0.0205*** | 0.0227*** |
| | (0.00188) | (0.00184) | (0.00388) | (0.00286) |
| Full Bathrooms | 0.110*** | 0.128*** | 0.0923*** | 0.0895*** |
| | (0.00245) | (0.00241) | (0.00340) | (0.00266) |
| Partial Bathrooms | 0.0623*** | 0.0722*** | 0.0485*** | 0.0460*** |
| | (0.00262) | (0.00256) | (0.00390) | (0.00299) |
| Square Feet of Living Space | 0.000562*** | 0.000571*** | 0.000414*** | 0.000401*** |
| | (6.20e-06) | (6.06e-06) | (1.24e-05) | (1.03e-05) |
| Square Feet$^2$ | -3.24e-08*** | -3.47e-08*** | -2.10e-08*** | -2.14e-08*** |
| | (1.02e-09) | (9.96e-10) | (2.47e-09) | (1.95e-09) |
| Lotsize (Acres) | 0.0152*** | 0.0152*** | 0.0201*** | 0.0202*** |
| | (0.000397) | (0.000388) | (0.00136) | (0.00126) |
| Lotsize$^2$ | -4.05e-05*** | -4.06e-05*** | -5.84e-05*** | -5.84e-05*** |
| | (1.91e-06) | (1.86e-06) | (8.78e-06) | (8.77e-06) |
| Lotsize Missing | 0.0560*** | 0.0143*** | -0.00999** | -0.00843** |
| | (0.00510) | (0.00503) | (0.00439) | (0.00390) |
| Has $<$ in Lot Dimensions | 0.0232*** | -0.00626* | -0.0219*** | -0.0210*** |
| | (0.00325) | (0.00320) | (0.00356) | (0.00287) |
| Has $>$ in Lot Dimensions | 0.0347* | 0.0172 | 0.00840 | 0.00454 |
| | (0.0183) | (0.0178) | (0.0124) | (0.0114) |
| Age (Years) | -0.00279*** | -0.00221*** | -0.00630*** | -0.00692*** |
| | (0.000118) | (0.000115) | (0.000397) | (0.000280) |
| Age$^2$ | -2.03e-05*** | -2.22e-05*** | 1.79e-05*** | 2.27e-05*** |
| | (1.10e-06) | (1.08e-06) | (4.47e-06) | (2.83e-06) |
| Age Unknown | -0.157*** | -0.159*** | -0.133*** | -0.126*** |
| | (0.0106) | (0.0103) | (0.0210) | (0.0174) |

Table A2 (continued)

| VARIABLES | (1) ln(Sales Price) | (2) ln(Sales Price) | (3) ln(Sales Price) | (4) ln(Sales Price) |
|---|---|---|---|---|
| Fireplace | 0.138*** | 0.126*** | 0.0497*** | 0.0495*** |
| | (0.00260) | (0.00255) | (0.00396) | (0.00300) |
| Basement | 0.164*** | 0.166*** | 0.151*** | 0.142*** |
| | (0.00261) | (0.00255) | (0.00439) | (0.00346) |
| Finished Basement | 0.0397*** | 0.0257*** | 0.0321*** | 0.0326*** |
| | (0.00322) | (0.00320) | (0.00445) | (0.00310) |
| Central Air | 0.396*** | 0.381*** | 0.259*** | 0.251*** |
| | (0.00390) | (0.00381) | (0.00929) | (0.00681) |
| Brick Exterior | 0.0602*** | 0.0488*** | 0.0404*** | 0.0352*** |
| | (0.00243) | (0.00238) | (0.00340) | (0.00267) |
| Vinyl Exterior | -0.0776*** | -0.0747*** | -0.0180*** | -0.0113** |
| | (0.00319) | (0.00312) | (0.00572) | (0.00489) |
| Metal Roof | -0.0659*** | -0.0235** | -0.0150 | -0.0121 |
| | (0.0119) | (0.0117) | (0.0164) | (0.0155) |
| Composition Roof | -0.0320*** | -0.000818 | 0.0153** | 0.0175*** |
| | (0.00491) | (0.00504) | (0.00684) | (0.00557) |
| Ranch Style | 0.0723*** | 0.0910*** | 0.0616*** | 0.0559*** |
| | (0.00267) | (0.00270) | (0.00397) | (0.00317) |
| Modular Style | -0.504*** | -0.466*** | -0.477*** | -0.480*** |
| | (0.00980) | (0.00961) | (0.0147) | (0.0148) |
| Cape Cod Style | 0.0974*** | 0.108*** | 0.0474*** | 0.0407*** |
| | (0.00408) | (0.00405) | (0.00569) | (0.00439) |
| Carport | 0.0455*** | 0.0481*** | 0.0136** | 0.00954** |
| | (0.00514) | (0.00502) | (0.00530) | (0.00454) |
| Garage | 0.0863*** | 0.0967*** | 0.00517 | 0.00433 |
| | (0.00331) | (0.00324) | (0.00557) | (0.00461) |
| One Car Garage | 0.119*** | 0.110*** | 0.0926*** | 0.0877*** |
| | (0.00423) | (0.00413) | (0.00595) | (0.00529) |
| Multiple Car Garage | 0.127*** | 0.124*** | 0.144*** | 0.140*** |
| | (0.00392) | (0.00383) | (0.00657) | (0.00544) |
| Within 1 Mile Parkway/Interstate | -0.0101*** | -0.0192*** | -0.0262*** | -0.0179** |
| | (0.00238) | (0.00233) | (0.00976) | (0.00708) |
| Within 1 Mile Railroad | -0.0861*** | -0.0917*** | -0.0134 | -0.0242*** |
| | (0.00230) | (0.00224) | (0.00917) | (0.00681) |
| Within 1 Mile Ft. Knox | -0.209*** | -0.208*** | -0.0765** | -0.0572* |
| | (0.00926) | (0.00904) | (0.0344) | (0.0322) |
| Constant | 10.37*** | 10.38*** | 10.50*** | 10.23*** |
| | (0.0104) | (0.0204) | (0.0315) | (0.0200) |
| Observations | 142,161 | 142,161 | 142,161 | 142,161 |
| R-squared | 0.703 | 0.718 | 0.853 | 0.862 |
| Year-Month Dummies | No | Yes | Yes | Yes |
| Tract Fixed Effects | No | No | Yes | No |
| Block Group Fixed Effects | No | No | No | Yes |

Table A3: Cross-Section Regression Results Showing the Effect of All Antennas on Property Values using the Inverse of Distance to the Nearest Antenna. Central Kentucky Data, 2000-2011. All Variables.

| VARIABLES | (1) ln(Sales Price) | (2) ln(Sales Price) | (3) ln(Sales Price) | (4) ln(Sales Price) |
|---|---|---|---|---|
| Inverse Distance to Any Antenna | 0.0805*** | 0.0902*** | -0.0358*** | -0.0284*** |
| | (0.00372) | (0.00364) | (0.00887) | (0.00755) |
| Bedrooms | -0.00160 | -0.00354* | 0.0202*** | 0.0226*** |
| | (0.00188) | (0.00184) | (0.00388) | (0.00286) |
| Full Bathrooms | 0.111*** | 0.128*** | 0.0927*** | 0.0896*** |
| | (0.00245) | (0.00241) | (0.00340) | (0.00267) |
| Partial Bathrooms | 0.0647*** | 0.0749*** | 0.0486*** | 0.0461*** |
| | (0.00261) | (0.00256) | (0.00389) | (0.00300) |
| Square Feet of Living Space | 0.000558*** | 0.000566*** | 0.000415*** | 0.000401*** |
| | (6.20e-06) | (6.06e-06) | (1.25e-05) | (1.04e-05) |
| Square Feet$^2$ | -3.20e-08*** | -3.41e-08*** | -2.11e-08*** | -2.14e-08*** |
| | (1.02e-09) | (9.96e-10) | (2.51e-09) | (1.96e-09) |
| Lotsize (Acres) | 0.0142*** | 0.0138*** | 0.0202*** | 0.0203*** |
| | (0.000391) | (0.000382) | (0.00137) | (0.00126) |
| Lotsize$^2$ | -3.70e-05*** | -3.59e-05*** | -5.90e-05*** | -5.88e-05*** |
| | (1.89e-06) | (1.85e-06) | (8.90e-06) | (8.84e-06) |
| Lotsize Missing | 0.0573*** | 0.0171*** | -0.0103** | -0.00829** |
| | (0.00509) | (0.00504) | (0.00437) | (0.00389) |
| Has $<$ in Lot Dimensions | 0.0264*** | -0.00144 | -0.0221*** | -0.0211*** |
| | (0.00324) | (0.00320) | (0.00359) | (0.00288) |
| Has $>$ in Lot Dimensions | 0.0363** | 0.0197 | 0.00840 | 0.00433 |
| | (0.0183) | (0.0178) | (0.0125) | (0.0115) |
| Age (Years) | -0.00256*** | -0.00191*** | -0.00632*** | -0.00693*** |
| | (0.000117) | (0.000115) | (0.000396) | (0.000280) |
| Age$^2$ | -2.23e-05*** | -2.47e-05*** | 1.80e-05*** | 2.27e-05*** |
| | (1.10e-06) | (1.07e-06) | (4.47e-06) | (2.84e-06) |
| Age Unknown | -0.162*** | -0.166*** | -0.134*** | -0.126*** |
| | (0.0105) | (0.0103) | (0.0211) | (0.0175) |

Table A3 (continued)

| VARIABLES | (1)<br>ln(Sales Price) | (2)<br>ln(Sales Price) | (3)<br>ln(Sales Price) | (4)<br>ln(Sales Price) |
|---|---|---|---|---|
| Fireplace | 0.139*** | 0.128*** | 0.0496*** | 0.0494*** |
| | (0.00260) | (0.00255) | (0.00397) | (0.00300) |
| Basement | 0.163*** | 0.165*** | 0.151*** | 0.142*** |
| | (0.00261) | (0.00256) | (0.00436) | (0.00347) |
| Finished Basement | 0.0387*** | 0.0249*** | 0.0323*** | 0.0326*** |
| | (0.00322) | (0.00320) | (0.00444) | (0.00310) |
| Central Air | 0.398*** | 0.385*** | 0.259*** | 0.251*** |
| | (0.00390) | (0.00381) | (0.00932) | (0.00682) |
| Brick Exterior | 0.0599*** | 0.0489*** | 0.0404*** | 0.0352*** |
| | (0.00243) | (0.00239) | (0.00342) | (0.00267) |
| Vinyl Exterior | -0.0798*** | -0.0776*** | -0.0179*** | -0.0110** |
| | (0.00319) | (0.00312) | (0.00569) | (0.00489) |
| Metal Roof | -0.0736*** | -0.0354*** | -0.0127 | -0.0101 |
| | (0.0119) | (0.0117) | (0.0163) | (0.0154) |
| Composition Roof | -0.0307*** | -0.000630 | 0.0156** | 0.0176*** |
| | (0.00491) | (0.00505) | (0.00682) | (0.00555) |
| Ranch Style | 0.0708*** | 0.0878*** | 0.0619*** | 0.0560*** |
| | (0.00266) | (0.00269) | (0.00396) | (0.00317) |
| Modular Style | -0.516*** | -0.484*** | -0.476*** | -0.479*** |
| | (0.00977) | (0.00957) | (0.0147) | (0.0149) |
| Cape Cod Style | 0.0970*** | 0.106*** | 0.0475*** | 0.0407*** |
| | (0.00408) | (0.00405) | (0.00570) | (0.00438) |
| Carport | 0.0451*** | 0.0475*** | 0.0131** | 0.00930** |
| | (0.00514) | (0.00502) | (0.00531) | (0.00454) |
| Garage | 0.0855*** | 0.0953*** | 0.00487 | 0.00418 |
| | (0.00331) | (0.00324) | (0.00556) | (0.00463) |
| One Car Garage | 0.121*** | 0.112*** | 0.0927*** | 0.0877*** |
| | (0.00423) | (0.00413) | (0.00595) | (0.00531) |
| Multiple Car Garage | 0.128*** | 0.125*** | 0.144*** | 0.140*** |
| | (0.00392) | (0.00383) | (0.00659) | (0.00546) |
| Within 1 Mile Parkway/Interstate | -0.00258 | -0.00855*** | -0.0288*** | -0.0212*** |
| | (0.00232) | (0.00226) | (0.00953) | (0.00699) |
| Within 1 Mile Railroad | -0.0817*** | -0.0855*** | -0.0153* | -0.0258*** |
| | (0.00227) | (0.00222) | (0.00907) | (0.00685) |
| Within 1 Mile Ft. Knox | -0.205*** | -0.202*** | -0.0749** | -0.0574* |
| | (0.00926) | (0.00904) | (0.0348) | (0.0332) |
| Constant | 10.29*** | 10.28*** | 10.56*** | 10.28*** |
| | (0.00994) | (0.0202) | (0.0302) | (0.0187) |
| Observations | 142,161 | 142,161 | 142,161 | 142,161 |
| R-squared | 0.703 | 0.717 | 0.853 | 0.862 |
| Year-Month Dummies | No | Yes | Yes | Yes |
| Tract Fixed Effects | No | No | Yes | No |
| Block Group Fixed Effects | No | No | No | Yes |

Table A4: Cross-Section Regression Results Showing the Effect of Towers Only on Property Values using a Continuous Measure of Distance. Central Kentucky Data, 2000-2011. All Variables.

| VARIABLES[a] | (1) ln(Sales Price) | (2) ln(Sales Price) | (3) ln(Sales Price) | (4) ln(Sales Price) |
|---|---|---|---|---|
| Distance to Tower | -0.00446*** | -0.00737*** | 0.0119*** | 0.0109*** |
| | (0.000597)[b] | (0.000585) | (0.00213) | (0.00187) |
| Distance$^2$ to Tower | 2.23e-05 | 6.31e-05*** | -0.000357*** | -0.000335*** |
| | (2.24e-05) | (2.19e-05) | (6.54e-05) | (6.04e-05) |
| Bedrooms | -0.00246 | -0.00462** | 0.0204*** | 0.0227*** |
| | (0.00188) | (0.00184) | (0.00388) | (0.00285) |
| Full Bathrooms | 0.110*** | 0.127*** | 0.0925*** | 0.0896*** |
| | (0.00245) | (0.00241) | (0.00343) | (0.00266) |
| Partial Bathrooms | 0.0631*** | 0.0729*** | 0.0485*** | 0.0461*** |
| | (0.00262) | (0.00257) | (0.00391) | (0.00300) |
| Square Feet of Living Space | 0.000559*** | 0.000567*** | 0.000414*** | 0.000401*** |
| | (6.20e-06) | (6.06e-06) | (1.24e-05) | (1.03e-05) |
| Square Feet$^2$ | -3.21e-08*** | -3.43e-08*** | -2.10e-08*** | -2.15e-08*** |
| | (1.02e-09) | (9.97e-10) | (2.48e-09) | (1.94e-09) |
| Lotsize (Acres) | 0.0148*** | 0.0148*** | 0.0200*** | 0.0202*** |
| | (0.000397) | (0.000387) | (0.00135) | (0.00126) |
| Lotsize$^2$ | -3.90e-05*** | -3.94e-05*** | -5.83e-05*** | -5.83e-05*** |
| | (1.91e-06) | (1.86e-06) | (8.76e-06) | (8.76e-06) |
| Lotsize Missing | 0.0569*** | 0.0154*** | -0.00987** | -0.00852** |
| | (0.00510) | (0.00504) | (0.00440) | (0.00390) |
| Has $<$ in Lot Dimensions | 0.0247*** | -0.00480 | -0.0218*** | -0.0210*** |
| | (0.00325) | (0.00320) | (0.00356) | (0.00287) |
| Has $>$ in Lot Dimensions | 0.0339* | 0.0165 | 0.00923 | 0.00477 |
| | (0.0183) | (0.0178) | (0.0124) | (0.0114) |
| Age (Years) | -0.00263*** | -0.00205*** | -0.00629*** | -0.00692*** |
| | (0.000118) | (0.000115) | (0.000396) | (0.000280) |
| Age$^2$ | -2.12e-05*** | -2.33e-05*** | 1.80e-05*** | 2.28e-05*** |
| | (1.10e-06) | (1.08e-06) | (4.45e-06) | (2.83e-06) |
| Age Unknown | -0.161*** | -0.162*** | -0.133*** | -0.126*** |
| | (0.0106) | (0.0103) | (0.0209) | (0.0174) |

Table A4 (continued)

| VARIABLES[a] | (1) ln(Sales Price) | (2) ln(Sales Price) | (3) ln(Sales Price) | (4) ln(Sales Price) |
|---|---|---|---|---|
| Fireplace | 0.138*** | 0.126*** | 0.0498*** | 0.0495*** |
| | (0.00260) | (0.00256) | (0.00394) | (0.00300) |
| Basement | 0.164*** | 0.167*** | 0.151*** | 0.142*** |
| | (0.00262) | (0.00256) | (0.00440) | (0.00346) |
| Finished Basement | 0.0391*** | 0.0254*** | 0.0320*** | 0.0325*** |
| | (0.00323) | (0.00320) | (0.00443) | (0.00309) |
| Central Air | 0.397*** | 0.383*** | 0.259*** | 0.251*** |
| | (0.00390) | (0.00381) | (0.00927) | (0.00680) |
| Brick Exterior | 0.0606*** | 0.0494*** | 0.0404*** | 0.0351*** |
| | (0.00243) | (0.00239) | (0.00340) | (0.00267) |
| Vinyl Exterior | -0.0786*** | -0.0759*** | -0.0178*** | -0.0112** |
| | (0.00320) | (0.00312) | (0.00573) | (0.00489) |
| Metal Roof | -0.0683*** | -0.0256** | -0.0153 | -0.0124 |
| | (0.0119) | (0.0117) | (0.0164) | (0.0155) |
| Composition Roof | -0.0316*** | -0.000844 | 0.0154** | 0.0175*** |
| | (0.00492) | (0.00505) | (0.00686) | (0.00559) |
| Ranch Style | 0.0711*** | 0.0901*** | 0.0613*** | 0.0560*** |
| | (0.00267) | (0.00270) | (0.00399) | (0.00318) |
| Modular Style | -0.508*** | -0.470*** | -0.478*** | -0.481*** |
| | (0.00981) | (0.00961) | (0.0147) | (0.0148) |
| Cape Cod Style | 0.0974*** | 0.108*** | 0.0473*** | 0.0406*** |
| | (0.00409) | (0.00405) | (0.00570) | (0.00440) |
| Carport | 0.0463*** | 0.0494*** | 0.0135** | 0.00966** |
| | (0.00514) | (0.00502) | (0.00532) | (0.00455) |
| Garage | 0.0872*** | 0.0977*** | 0.00524 | 0.00437 |
| | (0.00331) | (0.00324) | (0.00557) | (0.00461) |
| One Car Garage | 0.119*** | 0.110*** | 0.0928*** | 0.0876*** |
| | (0.00423) | (0.00414) | (0.00593) | (0.00528) |
| Multiple Car Garage | 0.127*** | 0.123*** | 0.143*** | 0.140*** |
| | (0.00392) | (0.00383) | (0.00654) | (0.00543) |
| Within 1 Mile Parkway/Interstate | -0.00583** | -0.0160*** | -0.0240** | -0.0163** |
| | (0.00238) | (0.00233) | (0.00983) | (0.00709) |
| Within 1 Mile Railroad | -0.0849*** | -0.0909*** | -0.0132 | -0.0239*** |
| | (0.00230) | (0.00224) | (0.00924) | (0.00698) |
| Within 1 Mile Ft. Knox | -0.209*** | -0.209*** | -0.0768** | -0.0569* |
| | (0.00928) | (0.00905) | (0.0342) | (0.0319) |
| Constant | 10.34*** | 10.36*** | 10.49*** | 10.22*** |
| | (0.0104) | (0.0204) | (0.0315) | (0.0205) |
| Observations | 142,161 | 142,161 | 142,161 | 142,161 |
| R-squared | 0.702 | 0.717 | 0.853 | 0.862 |
| Year-Month Dummies | No | Yes | Yes | Yes |
| Tract Fixed Effects | No | No | Yes | No |
| Block Group Fixed Effects | No | No | No | Yes |

Table A5: Cross-Section Regression Results Showing the Effect of All Antennas on Property Values Using the Nearest Antenna Method with the Closest Rings Combined. Central Kentucky Sales Data. 2000-2011. All Variables.

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| VARIABLES | ln(Sales Price) | ln(Sales Price) | ln(Sales Price) | ln(Sales Price) |
| Distance0to600 | 0.131*** | 0.140*** | -0.0630*** | -0.0572*** |
| | (0.0136) | (0.0133) | (0.0196) | (0.0178) |
| Distance600to900 | 0.0982*** | 0.111*** | -0.0756*** | -0.0699*** |
| | (0.0106) | (0.0104) | (0.0168) | (0.0152) |
| Distance900to1200 | 0.105*** | 0.121*** | -0.0697*** | -0.0727*** |
| | (0.00829) | (0.00809) | (0.0160) | (0.0141) |
| Distance1200to1500 | 0.110*** | 0.122*** | -0.0509*** | -0.0581*** |
| | (0.00689) | (0.00672) | (0.0119) | (0.0107) |
| Distance1500to1800 | 0.0798*** | 0.0911*** | -0.0600*** | -0.0687*** |
| | (0.00634) | (0.00619) | (0.0114) | (0.0106) |
| Distance1800to2100 | 0.0623*** | 0.0736*** | -0.0516*** | -0.0544*** |
| | (0.00603) | (0.00589) | (0.0113) | (0.0102) |
| Distance2100to2400 | 0.0425*** | 0.0565*** | -0.0511*** | -0.0536*** |
| | (0.00554) | (0.00541) | (0.0114) | (0.00964) |
| Distance2400to2700 | 0.0413*** | 0.0547*** | -0.0476*** | -0.0448*** |
| | (0.00535) | (0.00523) | (0.0106) | (0.00862) |
| Distance2700to3000 | 0.0115** | 0.0239*** | -0.0512*** | -0.0457*** |
| | (0.00510) | (0.00499) | (0.0108) | (0.00849) |
| Distance3000to3300 | 0.00454 | 0.0164*** | -0.0525*** | -0.0489*** |
| | (0.00504) | (0.00492) | (0.00990) | (0.00825) |
| Distance3300to3600 | 0.0232*** | 0.0337*** | -0.0406*** | -0.0360*** |
| | (0.00507) | (0.00495) | (0.00940) | (0.00778) |
| Distance3600to3900 | 0.0130*** | 0.0230*** | -0.0419*** | -0.0356*** |
| | (0.00501) | (0.00489) | (0.00918) | (0.00712) |
| Distance3900to4200 | 0.0239*** | 0.0327*** | -0.0275*** | -0.0201*** |
| | (0.00505) | (0.00493) | (0.00837) | (0.00660) |
| Distance4200to4500 | 0.0210*** | 0.0270*** | -0.0168** | -0.00857 |
| | (0.00521) | (0.00509) | (0.00707) | (0.00627) |
| Bedrooms | -0.00126 | -0.00326* | 0.0203*** | 0.0228*** |
| | (0.00188) | (0.00184) | (0.00373) | (0.00269) |
| Full Bathrooms | 0.110*** | 0.128*** | 0.0919*** | 0.0891*** |
| | (0.00244) | (0.00241) | (0.00329) | (0.00262) |
| Partial Bathrooms | 0.0645*** | 0.0748*** | 0.0480*** | 0.0459*** |
| | (0.00261) | (0.00256) | (0.00368) | (0.00288) |
| Square Feet of Living Space | 0.000559*** | 0.000567*** | 0.000415*** | 0.000401*** |
| | (6.19e-06) | (6.06e-06) | (1.23e-05) | (1.04e-05) |
| Square Feet$^2$ | -3.19e-08*** | -3.40e-08*** | -2.11e-08*** | -2.15e-08*** |
| | (1.02e-09) | (9.95e-10) | (2.47e-09) | (1.97e-09) |
| Lotsize (Acres) | 0.0142*** | 0.0140*** | 0.0201*** | 0.0203*** |
| | (0.000392) | (0.000382) | (0.00134) | (0.00126) |
| Lotsize$^2$ | -3.71e-05*** | -3.64e-05*** | -5.87e-05*** | -5.86e-05*** |
| | (1.89e-06) | (1.85e-06) | (8.85e-06) | (8.84e-06) |
| Lotsize Missing | 0.0574*** | 0.0169*** | -0.0100** | -0.00844** |
| | (0.00509) | (0.00503) | (0.00422) | (0.00377) |
| Has $<$ in Lot Dimensions | 0.0269*** | -0.00157 | -0.0218*** | -0.0209*** |
| | (0.00324) | (0.00319) | (0.00343) | (0.00281) |
| Has $>$ in Lot Dimensions | 0.0369** | 0.0203 | 0.00781 | 0.00404 |
| | (0.0182) | (0.0178) | (0.0122) | (0.0114) |

Table A5 (continued)

| VARIABLES | (1)<br>ln(Sales Price) | (2)<br>ln(Sales Price) | (3)<br>ln(Sales Price) | (4)<br>ln(Sales Price) |
|---|---|---|---|---|
| Age (Years) | -0.00258*** | -0.00197*** | -0.00632*** | -0.00693*** |
| | (0.000117) | (0.000115) | (0.000375) | (0.000277) |
| $Age^2$ | -2.27e-05*** | -2.50e-05*** | 1.82e-05*** | 2.30e-05*** |
| | (1.10e-06) | (1.07e-06) | (4.24e-06) | (2.81e-06) |
| Age Unknown | -0.162*** | -0.164*** | -0.134*** | -0.126*** |
| | (0.0105) | (0.0103) | (0.0203) | (0.0174) |
| Fireplace | 0.138*** | 0.126*** | 0.0499*** | 0.0497*** |
| | (0.00260) | (0.00255) | (0.00385) | (0.00291) |
| Basement | 0.162*** | 0.165*** | 0.151*** | 0.142*** |
| | (0.00261) | (0.00255) | (0.00434) | (0.00336) |
| Finished Basement | 0.0391*** | 0.0254*** | 0.0320*** | 0.0326*** |
| | (0.00322) | (0.00319) | (0.00434) | (0.00308) |
| Central Air | 0.397*** | 0.383*** | 0.259*** | 0.251*** |
| | (0.00389) | (0.00381) | (0.00905) | (0.00683) |
| Brick Exterior | 0.0602*** | 0.0492*** | 0.0403*** | 0.0350*** |
| | (0.00243) | (0.00238) | (0.00323) | (0.00251) |
| Vinyl Exterior | -0.0798*** | -0.0775*** | -0.0172*** | -0.0110** |
| | (0.00319) | (0.00312) | (0.00553) | (0.00481) |
| Metal Roof | -0.0719*** | -0.0320*** | -0.0148 | -0.0117 |
| | (0.0119) | (0.0117) | (0.0163) | (0.0154) |
| Composition Roof | -0.0308*** | -0.000276 | 0.0151** | 0.0172*** |
| | (0.00491) | (0.00504) | (0.00667) | (0.00539) |
| Ranch Style | 0.0714*** | 0.0891*** | 0.0618*** | 0.0560*** |
| | (0.00266) | (0.00269) | (0.00391) | (0.00305) |
| Modular Style | -0.515*** | -0.481*** | -0.476*** | -0.479*** |
| | (0.00977) | (0.00957) | (0.0154) | (0.0150) |
| Cape Cod Style | 0.0958*** | 0.105*** | 0.0477*** | 0.0408*** |
| | (0.00408) | (0.00405) | (0.00565) | (0.00440) |
| Carport | 0.0448*** | 0.0471*** | 0.0138*** | 0.00985** |
| | (0.00514) | (0.00502) | (0.00520) | (0.00456) |
| Garage | 0.0845*** | 0.0942*** | 0.00528 | 0.00452 |
| | (0.00330) | (0.00324) | (0.00542) | (0.00452) |
| One Car Garage | 0.121*** | 0.112*** | 0.0926*** | 0.0875*** |
| | (0.00422) | (0.00413) | (0.00585) | (0.00523) |
| Multiple Car Garage | 0.129*** | 0.127*** | 0.144*** | 0.140*** |
| | (0.00391) | (0.00383) | (0.00647) | (0.00536) |
| Within 1 Mile Parkway/Interstate | -0.00430* | -0.0118*** | -0.0281*** | -0.0192** |
| | (0.00234) | (0.00229) | (0.00977) | (0.00751) |
| Within 1 Mile Railroad | -0.0815*** | -0.0852*** | -0.0149* | -0.0255*** |
| | (0.00227) | (0.00222) | (0.00905) | (0.00692) |
| Within 1 Mile Ft. Knox | -0.206*** | -0.204*** | -0.0734** | -0.0535 |
| | (0.00926) | (0.00904) | (0.0320) | (0.0328) |
| Constant | 10.29*** | 10.28*** | 10.56*** | 10.30*** |
| | (0.00993) | (0.0201) | (0.0295) | (0.0194) |
| Observations | 142,164 | 142,164 | 142,164 | 142,164 |
| R-squared | 0.703 | 0.718 | 0.853 | 0.862 |
| Year-Month Dummies | No | Yes | Yes | Yes |
| Tract Fixed Effects | No | No | Yes | No |
| Block Group Fixed Effects | No | No | No | Yes |

Table A6: Cross-Section Regression Results Showing the Effect of Towers Only on Property Values Using the Nearest Antenna Method with the Closest Rings Combined. Central Kentucky Sales Data. 2000-2011. All Variables.

| VARIABLES | (1)<br>ln(Sales Price) | (2)<br>ln(Sales Price) | (3)<br>ln(Sales Price) | (4)<br>ln(Sales Price) |
|---|---|---|---|---|
| TowerDistance0to600 | 0.124*** | 0.135*** | -0.0645*** | -0.0503** |
| | (0.0155) | (0.0151) | (0.0232) | (0.0213) |
| TowerDistance600to900 | 0.0828*** | 0.0960*** | -0.0798*** | -0.0680*** |
| | (0.0120) | (0.0118) | (0.0185) | (0.0175) |
| TowerDistance900to1200 | 0.0894*** | 0.106*** | -0.0726*** | -0.0726*** |
| | (0.00940) | (0.00918) | (0.0205) | (0.0165) |
| TowerDistance1200to1500 | 0.0897*** | 0.104*** | -0.0567*** | -0.0620*** |
| | (0.00772) | (0.00754) | (0.0132) | (0.0121) |
| TowerDistance1500to1800 | 0.0592*** | 0.0732*** | -0.0652*** | -0.0720*** |
| | (0.00702) | (0.00686) | (0.0126) | (0.0119) |
| TowerDistance1800to2100 | 0.0494*** | 0.0625*** | -0.0554*** | -0.0596*** |
| | (0.00660) | (0.00645) | (0.0128) | (0.0112) |
| TowerDistance2100to2400 | 0.0267*** | 0.0426*** | -0.0538*** | -0.0582*** |
| | (0.00597) | (0.00583) | (0.0126) | (0.0105) |
| TowerDistance2400to2700 | 0.0212*** | 0.0364*** | -0.0538*** | -0.0540*** |
| | (0.00579) | (0.00566) | (0.0116) | (0.00930) |
| TowerDistance2700to3000 | -0.0122** | 0.00154 | -0.0558*** | -0.0546*** |
| | (0.00555) | (0.00542) | (0.0116) | (0.00916) |
| TowerDistance3000to3300 | -0.0199*** | -0.00485 | -0.0522*** | -0.0516*** |
| | (0.00541) | (0.00529) | (0.0108) | (0.00902) |
| TowerDistance3300to3600 | -0.00121 | 0.0114** | -0.0471*** | -0.0424*** |
| | (0.00539) | (0.00526) | (0.0103) | (0.00842) |
| TowerDistance3600to3900 | 0.000655 | 0.0134*** | -0.0445*** | -0.0411*** |
| | (0.00519) | (0.00507) | (0.00888) | (0.00757) |
| TowerDistance3900to4200 | 0.0222*** | 0.0327*** | -0.0279*** | -0.0253*** |
| | (0.00514) | (0.00502) | (0.00843) | (0.00723) |
| TowerDistance4200to4500 | 0.0182*** | 0.0276*** | -0.0201*** | -0.0139** |
| | (0.00529) | (0.00517) | (0.00717) | (0.00662) |
| Bedrooms | -0.00110 | -0.00298 | 0.0202*** | 0.0227*** |
| | (0.00188) | (0.00184) | (0.00375) | (0.00268) |
| Full Bathrooms | 0.110*** | 0.127*** | 0.0923*** | 0.0893*** |
| | (0.00245) | (0.00241) | (0.00329) | (0.00260) |
| Partial Bathrooms | 0.0646*** | 0.0747*** | 0.0484*** | 0.0461*** |
| | (0.00261) | (0.00256) | (0.00370) | (0.00287) |
| Square Feet of Living Space | 0.000558*** | 0.000565*** | 0.000414*** | 0.000401*** |
| | (6.20e-06) | (6.06e-06) | (1.24e-05) | (1.04e-05) |
| Square Feet$^2$ | -3.19e-08*** | -3.39e-08*** | -2.10e-08*** | -2.14e-08*** |
| | (1.02e-09) | (9.96e-10) | (2.49e-09) | (1.96e-09) |
| Lotsize (Acres) | 0.0140*** | 0.0137*** | 0.0201*** | 0.0203*** |
| | (0.000392) | (0.000382) | (0.00134) | (0.00126) |
| Lotsize$^2$ | -3.62e-05*** | -3.55e-05*** | -5.87e-05*** | -5.85e-05*** |
| | (1.89e-06) | (1.85e-06) | (8.86e-06) | (8.85e-06) |
| Lotsize Missing | 0.0579*** | 0.0179*** | -0.0102** | -0.00853** |
| | (0.00510) | (0.00504) | (0.00419) | (0.00377) |
| Has $<$ in Lot Dimensions | 0.0278*** | -0.000432 | -0.0218*** | -0.0210*** |
| | (0.00324) | (0.00320) | (0.00342) | (0.00281) |
| Has $>$ in Lot Dimensions | 0.0349* | 0.0185 | 0.00824 | 0.00406 |
| | (0.0183) | (0.0178) | (0.0122) | (0.0114) |

Table A6 (continued)

| VARIABLES | (1)<br>ln(Sales Price) | (2)<br>ln(Sales Price) | (3)<br>ln(Sales Price) | (4)<br>ln(Sales Price) |
|---|---|---|---|---|
| Age (Years) | -0.00246*** | -0.00183*** | -0.00629*** | -0.00693*** |
| | (0.000117) | (0.000115) | (0.000375) | (0.000277) |
| $Age^2$ | -2.33e-05*** | -2.58e-05*** | 1.81e-05*** | 2.30e-05*** |
| | (1.10e-06) | (1.08e-06) | (4.23e-06) | (2.80e-06) |
| Age Unknown | -0.166*** | -0.168*** | -0.134*** | -0.126*** |
| | (0.0105) | (0.0103) | (0.0203) | (0.0173) |
| Fireplace | 0.138*** | 0.127*** | 0.0498*** | 0.0497*** |
| | (0.00260) | (0.00256) | (0.00385) | (0.00292) |
| Basement | 0.163*** | 0.165*** | 0.151*** | 0.142*** |
| | (0.00261) | (0.00256) | (0.00434) | (0.00334) |
| Finished Basement | 0.0380*** | 0.0246*** | 0.0322*** | 0.0325*** |
| | (0.00322) | (0.00320) | (0.00432) | (0.00307) |
| Central Air | 0.398*** | 0.385*** | 0.258*** | 0.251*** |
| | (0.00390) | (0.00381) | (0.00905) | (0.00682) |
| Brick Exterior | 0.0609*** | 0.0502*** | 0.0402*** | 0.0350*** |
| | (0.00243) | (0.00239) | (0.00325) | (0.00251) |
| Vinyl Exterior | -0.0801*** | -0.0780*** | -0.0171*** | -0.0108** |
| | (0.00319) | (0.00312) | (0.00555) | (0.00481) |
| Metal Roof | -0.0735*** | -0.0343*** | -0.0145 | -0.0115 |
| | (0.0119) | (0.0117) | (0.0163) | (0.0155) |
| Composition Roof | -0.0304*** | -0.000416 | 0.0153** | 0.0172*** |
| | (0.00491) | (0.00505) | (0.00667) | (0.00540) |
| Ranch Style | 0.0703*** | 0.0878*** | 0.0619*** | 0.0562*** |
| | (0.00267) | (0.00270) | (0.00394) | (0.00305) |
| Modular Style | -0.518*** | -0.484*** | -0.476*** | -0.479*** |
| | (0.00977) | (0.00958) | (0.0154) | (0.0150) |
| Cape Cod Style | 0.0962*** | 0.106*** | 0.0475*** | 0.0406*** |
| | (0.00408) | (0.00405) | (0.00567) | (0.00439) |
| Carport | 0.0458*** | 0.0484*** | 0.0135*** | 0.00989** |
| | (0.00514) | (0.00502) | (0.00521) | (0.00456) |
| Garage | 0.0856*** | 0.0952*** | 0.00524 | 0.00453 |
| | (0.00331) | (0.00324) | (0.00541) | (0.00452) |
| One Car Garage | 0.121*** | 0.112*** | 0.0925*** | 0.0874*** |
| | (0.00423) | (0.00413) | (0.00581) | (0.00522) |
| Multiple Car Garage | 0.129*** | 0.126*** | 0.144*** | 0.140*** |
| | (0.00392) | (0.00383) | (0.00644) | (0.00535) |
| Within 1 Mile Parkway/Interstate | -0.000183 | -0.00760*** | -0.0263*** | -0.0180** |
| | (0.00233) | (0.00228) | (0.00973) | (0.00746) |
| Within 1 Mile Railroad | -0.0808*** | -0.0846*** | -0.0145 | -0.0252*** |
| | (0.00227) | (0.00222) | (0.00913) | (0.00700) |
| Within 1 Mile Ft. Knox | -0.206*** | -0.205*** | -0.0727** | -0.0527 |
| | (0.00927) | (0.00905) | (0.0319) | (0.0326) |
| Constant | 10.30*** | 10.29*** | 10.55*** | 10.30*** |
| | (0.00993) | (0.0202) | (0.0295) | (0.0196) |
| Observations | 142,164 | 142,164 | 142,164 | 142,164 |
| R-squared | 0.703 | 0.717 | 0.853 | 0.862 |
| Year-Month Dummies | No | Yes | Yes | Yes |
| Tract Fixed Effects | No | Yes | No | Yes |
| Block Group Fixed Effects | No | No | No | Yes |

Table A7: Cross-Section Regression Results Showing the Effect of All Antennas on Property Values Using the Antenna Count Method with the Closest Rings Combined. Central Kentucky Sales Data. 2000-2011. All Variables.

| VARIABLES | (1) ln(Sales Price) | (2) ln(Sales Price) | (3) ln(Sales Price) | (4) ln(Sales Price) |
|---|---|---|---|---|
| Count0to600 | 0.0993*** | 0.100*** | -0.0384** | -0.0307** |
| | (0.0129) | (0.0126) | (0.0166) | (0.0148) |
| Count600to900 | 0.0636*** | 0.0693*** | -0.0502*** | -0.0458*** |
| | (0.00981) | (0.00957) | (0.0146) | (0.0133) |
| Count900to1200 | 0.0697*** | 0.0784*** | -0.0432*** | -0.0483*** |
| | (0.00766) | (0.00748) | (0.0131) | (0.0118) |
| Count1200to1500 | 0.0732*** | 0.0787*** | -0.0307*** | -0.0371*** |
| | (0.00617) | (0.00602) | (0.00973) | (0.00900) |
| Count1500to1800 | 0.0493*** | 0.0536*** | -0.0397*** | -0.0480*** |
| | (0.00551) | (0.00538) | (0.00810) | (0.00769) |
| Count1800to2100 | 0.0453*** | 0.0494*** | -0.0291*** | -0.0315*** |
| | (0.00502) | (0.00490) | (0.00795) | (0.00719) |
| Count2100to2400 | 0.0299*** | 0.0363*** | -0.0264*** | -0.0303*** |
| | (0.00451) | (0.00440) | (0.00870) | (0.00702) |
| Count2400to2700 | 0.0305*** | 0.0362*** | -0.0289*** | -0.0277*** |
| | (0.00418) | (0.00408) | (0.00706) | (0.00635) |
| Count2700to3000 | 0.00339 | 0.00958** | -0.0307*** | -0.0286*** |
| | (0.00385) | (0.00376) | (0.00739) | (0.00608) |
| Count3000to3300 | 0.00398 | 0.00951*** | -0.0299*** | -0.0311*** |
| | (0.00362) | (0.00353) | (0.00694) | (0.00557) |
| Count3300to3600 | 0.0167*** | 0.0213*** | -0.0251*** | -0.0239*** |
| | (0.00349) | (0.00340) | (0.00608) | (0.00482) |
| Count3600to3900 | 0.00973*** | 0.0147*** | -0.0291*** | -0.0274*** |
| | (0.00323) | (0.00315) | (0.00626) | (0.00504) |
| Count3900to4200 | 0.0255*** | 0.0304*** | -0.0237*** | -0.0196*** |
| | (0.00306) | (0.00299) | (0.00652) | (0.00465) |
| Count4200to4500 | 0.0215*** | 0.0266*** | -0.0191*** | -0.0140*** |
| | (0.00302) | (0.00295) | (0.00613) | (0.00458) |
| Bedrooms | -0.00113 | -0.00309* | 0.0205*** | 0.0229*** |
| | (0.00188) | (0.00184) | (0.00376) | (0.00270) |
| Full Bathrooms | 0.110*** | 0.127*** | 0.0920*** | 0.0891*** |
| | (0.00244) | (0.00241) | (0.00330) | (0.00263) |
| Partial Bathrooms | 0.0649*** | 0.0754*** | 0.0486*** | 0.0462*** |
| | (0.00261) | (0.00256) | (0.00371) | (0.00288) |
| Square Feet of Living Space | 0.000560*** | 0.000568*** | 0.000414*** | 0.000400*** |
| | (6.20e-06) | (6.06e-06) | (1.23e-05) | (1.04e-05) |
| Square Feet$^2$ | -3.20e-08*** | -3.42e-08*** | -2.10e-08*** | -2.13e-08*** |
| | (1.02e-09) | (9.95e-10) | (2.48e-09) | (1.97e-09) |
| Lotsize (Acres) | 0.0141*** | 0.0139*** | 0.0201*** | 0.0202*** |
| | (0.000390) | (0.000381) | (0.00136) | (0.00127) |
| Lotsize$^2$ | -3.70e-05*** | -3.61e-05*** | -5.86e-05*** | -5.84e-05*** |
| | (1.89e-06) | (1.84e-06) | (8.94e-06) | (8.87e-06) |
| Lotsize Missing | 0.0581*** | 0.0172*** | -0.0103** | -0.00854** |
| | (0.00509) | (0.00503) | (0.00418) | (0.00376) |
| Has $<$ in Lot Dimensions | 0.0272*** | -0.00113 | -0.0221*** | -0.0211*** |
| | (0.00324) | (0.00319) | (0.00345) | (0.00283) |
| Has $>$ in Lot Dimensions | 0.0367** | 0.0199 | 0.00671 | 0.00363 |
| | (0.0183) | (0.0178) | (0.0121) | (0.0113) |

Table A7 (continued)

| VARIABLES | (1)<br>ln(Sales Price) | (2)<br>ln(Sales Price) | (3)<br>ln(Sales Price) | (4)<br>ln(Sales Price) |
|---|---|---|---|---|
| Age (Years) | -0.00256*** | -0.00192*** | -0.00637*** | -0.00697*** |
| | (0.000117) | (0.000115) | (0.000378) | (0.000280) |
| $Age^2$ | -2.35e-05*** | -2.61e-05*** | 1.88e-05*** | 2.34e-05*** |
| | (1.10e-06) | (1.08e-06) | (4.23e-06) | (2.83e-06) |
| Age Unknown | -0.165*** | -0.168*** | -0.136*** | -0.128*** |
| | (0.0105) | (0.0103) | (0.0207) | (0.0175) |
| Fireplace | 0.138*** | 0.126*** | 0.0496*** | 0.0496*** |
| | (0.00260) | (0.00255) | (0.00381) | (0.00290) |
| Basement | 0.162*** | 0.165*** | 0.152*** | 0.143*** |
| | (0.00261) | (0.00255) | (0.00431) | (0.00337) |
| Finished Basement | 0.0398*** | 0.0259*** | 0.0324*** | 0.0327*** |
| | (0.00322) | (0.00319) | (0.00434) | (0.00308) |
| Central Air | 0.396*** | 0.383*** | 0.258*** | 0.251*** |
| | (0.00389) | (0.00381) | (0.00904) | (0.00684) |
| Brick Exterior | 0.0597*** | 0.0485*** | 0.0406*** | 0.0354*** |
| | (0.00243) | (0.00238) | (0.00326) | (0.00252) |
| Vinyl Exterior | -0.0800*** | -0.0778*** | -0.0170*** | -0.0107** |
| | (0.00319) | (0.00311) | (0.00558) | (0.00483) |
| Metal Roof | -0.0728*** | -0.0329*** | -0.0176 | -0.0138 |
| | (0.0118) | (0.0117) | (0.0162) | (0.0155) |
| Composition Roof | -0.0327*** | -0.00198 | 0.0127* | 0.0152*** |
| | (0.00491) | (0.00504) | (0.00654) | (0.00538) |
| Ranch Style | 0.0722*** | 0.0900*** | 0.0616*** | 0.0562*** |
| | (0.00266) | (0.00269) | (0.00394) | (0.00307) |
| Modular Style | -0.514*** | -0.482*** | -0.477*** | -0.480*** |
| | (0.00977) | (0.00957) | (0.0156) | (0.0151) |
| Cape Cod Style | 0.0944*** | 0.104*** | 0.0477*** | 0.0412*** |
| | (0.00408) | (0.00405) | (0.00567) | (0.00443) |
| Carport | 0.0465*** | 0.0488*** | 0.0142*** | 0.0104** |
| | (0.00514) | (0.00502) | (0.00526) | (0.00458) |
| Garage | 0.0850*** | 0.0949*** | 0.00566 | 0.00498 |
| | (0.00330) | (0.00324) | (0.00544) | (0.00450) |
| One Car Garage | 0.121*** | 0.113*** | 0.0923*** | 0.0871*** |
| | (0.00422) | (0.00413) | (0.00585) | (0.00515) |
| Multiple Car Garage | 0.131*** | 0.128*** | 0.143*** | 0.139*** |
| | (0.00392) | (0.00383) | (0.00643) | (0.00528) |
| Within 1 Mile Parkway/Interstate | -0.00640*** | -0.0139*** | -0.0281*** | -0.0193** |
| | (0.00234) | (0.00229) | (0.00964) | (0.00771) |
| Within 1 Mile Railroad | -0.0838*** | -0.0882*** | -0.0128 | -0.0232*** |
| | (0.00228) | (0.00222) | (0.00906) | (0.00691) |
| Within 1 Mile Ft. Knox | -0.204*** | -0.201*** | -0.0747** | -0.0555 |
| | (0.00925) | (0.00903) | (0.0327) | (0.0339) |
| Constant | 10.29*** | 10.29*** | 10.56*** | 10.31*** |
| | (0.00992) | (0.0201) | (0.0294) | (0.0206) |
| Observations | 142,164 | 142,164 | 142,164 | 142,164 |
| R-squared | 0.703 | 0.718 | 0.853 | 0.862 |
| Year-Month Dummies | No | Yes | Yes | Yes |
| Tract Fixed Effects | No | No | Yes | No |
| Block Group Fixed Effects | No | No | No | Yes |

Table A8: Cross-Section Regression Results Showing the Effect of Towers Only on Property Values Using Antenna Count Method with the Closest Rings Combined. Central Kentucky Sales Data. 2000-2011. All Variables.

| VARIABLES | (1) ln(Sales Price) | (2) ln(Sales Price) | (3) ln(Sales Price) | (4) ln(Sales Price) |
|---|---|---|---|---|
| TowerCount0to600 | 0.103*** | 0.106*** | -0.0459** | -0.0317* |
| | (0.0150) | (0.0146) | (0.0211) | (0.0188) |
| TowerCount600to900 | 0.0602*** | 0.0669*** | -0.0661*** | -0.0555*** |
| | (0.0117) | (0.0114) | (0.0164) | (0.0155) |
| TowerCount900to1200 | 0.0670*** | 0.0772*** | -0.0586*** | -0.0591*** |
| | (0.00909) | (0.00887) | (0.0183) | (0.0152) |
| TowerCount1200to1500 | 0.0634*** | 0.0715*** | -0.0490*** | -0.0521*** |
| | (0.00736) | (0.00718) | (0.0133) | (0.0113) |
| TowerCount1500to1800 | 0.0374*** | 0.0452*** | -0.0581*** | -0.0614*** |
| | (0.00663) | (0.00648) | (0.0103) | (0.00973) |
| TowerCount1800to2100 | 0.0318*** | 0.0395*** | -0.0451*** | -0.0474*** |
| | (0.00603) | (0.00589) | (0.0100) | (0.00906) |
| TowerCount2100to2400 | 0.0125** | 0.0223*** | -0.0407*** | -0.0452*** |
| | (0.00536) | (0.00524) | (0.0109) | (0.00908) |
| TowerCount2400to2700 | 0.0164*** | 0.0255*** | -0.0402*** | -0.0422*** |
| | (0.00499) | (0.00487) | (0.00895) | (0.00763) |
| TowerCount2700to3000 | -0.00973** | -0.000863 | -0.0403*** | -0.0419*** |
| | (0.00464) | (0.00454) | (0.00987) | (0.00804) |
| TowerCount3000to3300 | -0.0140*** | -0.00411 | -0.0425*** | -0.0446*** |
| | (0.00437) | (0.00427) | (0.00865) | (0.00714) |
| TowerCount3300to3600 | -0.00606 | 0.00189 | -0.0393*** | -0.0384*** |
| | (0.00425) | (0.00415) | (0.00759) | (0.00637) |
| TowerCount3600to3900 | -0.00697* | 0.00108 | -0.0392*** | -0.0385*** |
| | (0.00388) | (0.00379) | (0.00748) | (0.00614) |
| TowerCount3900to4200 | 0.0218*** | 0.0284*** | -0.0279*** | -0.0274*** |
| | (0.00369) | (0.00361) | (0.00754) | (0.00583) |
| TowerCount4200to4500 | 0.0165*** | 0.0243*** | -0.0203*** | -0.0185*** |
| | (0.00360) | (0.00352) | (0.00716) | (0.00558) |
| Bedrooms | -0.00136 | -0.00316* | 0.0204*** | 0.0229*** |
| | (0.00188) | (0.00184) | (0.00376) | (0.00269) |
| Full Bathrooms | 0.110*** | 0.127*** | 0.0920*** | 0.0890*** |
| | (0.00245) | (0.00241) | (0.00330) | (0.00260) |
| Partial Bathrooms | 0.0649*** | 0.0751*** | 0.0486*** | 0.0462*** |
| | (0.00261) | (0.00257) | (0.00371) | (0.00288) |
| Square Feet of Living Space | 0.000558*** | 0.000565*** | 0.000413*** | 0.000400*** |
| | (6.20e-06) | (6.07e-06) | (1.24e-05) | (1.03e-05) |
| Square Feet$^2$ | -3.19e-08*** | -3.39e-08*** | -2.09e-08*** | -2.13e-08*** |
| | (1.02e-09) | (9.97e-10) | (2.48e-09) | (1.95e-09) |
| Lotsize (Acres) | 0.0138*** | 0.0136*** | 0.0200*** | 0.0201*** |
| | (0.000391) | (0.000382) | (0.00136) | (0.00127) |
| Lotsize$^2$ | -3.60e-05*** | -3.52e-05*** | -5.85e-05*** | -5.83e-05*** |
| | (1.89e-06) | (1.85e-06) | (8.93e-06) | (8.87e-06) |
| Lotsize Missing | 0.0581*** | 0.0182*** | -0.0102** | -0.00871** |
| | (0.00510) | (0.00504) | (0.00417) | (0.00375) |
| Has $<$ in Lot Dimensions | 0.0279*** | 5.40e-06 | -0.0219*** | -0.0212*** |
| | (0.00325) | (0.00320) | (0.00343) | (0.00283) |
| Has $>$ in Lot Dimensions | 0.0345* | 0.0180 | 0.00789 | 0.00386 |
| | (0.0183) | (0.0179) | (0.0121) | (0.0113) |

Table A8 (continued)

| VARIABLES | (1)<br>ln(Sales Price) | (2)<br>ln(Sales Price) | (3)<br>ln(Sales Price) | (4)<br>ln(Sales Price) |
|---|---|---|---|---|
| Age (Years) | -0.00244*** | -0.00179*** | -0.00634*** | -0.00696*** |
| | (0.000117) | (0.000115) | (0.000377) | (0.000279) |
| $Age^2$ | -2.33e-05*** | -2.63e-05*** | 1.88e-05*** | 2.35e-05*** |
| | (1.11e-06) | (1.08e-06) | (4.20e-06) | (2.81e-06) |
| Age Unknown | -0.169*** | -0.171*** | -0.136*** | -0.128*** |
| | (0.0105) | (0.0103) | (0.0206) | (0.0174) |
| Fireplace | 0.139*** | 0.127*** | 0.0496*** | 0.0495*** |
| | (0.00260) | (0.00256) | (0.00381) | (0.00290) |
| Basement | 0.163*** | 0.165*** | 0.151*** | 0.142*** |
| | (0.00262) | (0.00256) | (0.00431) | (0.00334) |
| Finished Basement | 0.0383*** | 0.0248*** | 0.0328*** | 0.0329*** |
| | (0.00323) | (0.00320) | (0.00432) | (0.00307) |
| Central Air | 0.398*** | 0.385*** | 0.258*** | 0.250*** |
| | (0.00390) | (0.00381) | (0.00903) | (0.00683) |
| Brick Exterior | 0.0606*** | 0.0497*** | 0.0405*** | 0.0354*** |
| | (0.00243) | (0.00239) | (0.00327) | (0.00252) |
| Vinyl Exterior | -0.0798*** | -0.0778*** | -0.0168*** | -0.0104** |
| | (0.00320) | (0.00312) | (0.00558) | (0.00484) |
| Metal Roof | -0.0750*** | -0.0360*** | -0.0174 | -0.0139 |
| | (0.0119) | (0.0117) | (0.0163) | (0.0155) |
| Composition Roof | -0.0322*** | -0.00226 | 0.0128* | 0.0150*** |
| | (0.00492) | (0.00505) | (0.00653) | (0.00537) |
| Ranch Style | 0.0701*** | 0.0875*** | 0.0618*** | 0.0562*** |
| | (0.00267) | (0.00270) | (0.00396) | (0.00307) |
| Modular Style | -0.518*** | -0.485*** | -0.477*** | -0.480*** |
| | (0.00979) | (0.00959) | (0.0156) | (0.0151) |
| Cape Cod Style | 0.0960*** | 0.105*** | 0.0475*** | 0.0407*** |
| | (0.00409) | (0.00406) | (0.00565) | (0.00441) |
| Carport | 0.0468*** | 0.0494*** | 0.0144*** | 0.0107** |
| | (0.00515) | (0.00503) | (0.00526) | (0.00458) |
| Garage | 0.0865*** | 0.0964*** | 0.00581 | 0.00517 |
| | (0.00331) | (0.00325) | (0.00542) | (0.00447) |
| One Car Garage | 0.121*** | 0.113*** | 0.0918*** | 0.0867*** |
| | (0.00423) | (0.00414) | (0.00580) | (0.00512) |
| Multiple Car Garage | 0.128*** | 0.126*** | 0.143*** | 0.139*** |
| | (0.00392) | (0.00384) | (0.00638) | (0.00525) |
| Within 1 Mile Parkway/Interstate | 0.000163 | -0.00718*** | -0.0261*** | -0.0181** |
| | (0.00233) | (0.00228) | (0.00977) | (0.00753) |
| Within 1 Mile Railroad | -0.0808*** | -0.0854*** | -0.0134 | -0.0235*** |
| | (0.00228) | (0.00223) | (0.00927) | (0.00702) |
| Within 1 Mile Ft. Knox | -0.204*** | -0.203*** | -0.0741** | -0.0536 |
| | (0.00927) | (0.00906) | (0.0328) | (0.0337) |
| Constant | 10.30*** | 10.29*** | 10.56*** | 10.34*** |
| | (0.00993) | (0.0202) | (0.0294) | (0.0216) |
| Observations | 142,164 | 142,164 | 142,164 | 142,164 |
| R-squared | 0.702 | 0.717 | 0.853 | 0.862 |
| Year-Month Dummies | No | Yes | Yes | Yes |
| Tract Fixed Effects | No | No | Yes | No |
| Block Group Fixed Effects | No | No | No | Yes |

Table A9: Cross-Section Regression Results Showing the Effect of Towers Only on Property Values using a Continuous Measure of Distance with the Density of Nearby Antennas. Central Kentucky Data, 2000-2011.

| VARIABLES | (1)<br>ln(Sales Price) | (2)<br>ln(Sales Price) | (3)<br>ln(Sales Price) | (4)<br>ln(Sales Price) |
|---|---|---|---|---|
| Distance to Tower | -0.00164** | -0.00384*** | 0.00453* | 0.00274 |
| | (0.000808) | (0.000789) | (0.00233) | (0.00208) |
| Distance$^2$ to Tower | -6.31e-05** | -4.11e-05 | -0.000161** | -0.000118* |
| | (2.72e-05) | (2.66e-05) | (6.46e-05) | (6.16e-05) |
| Constant | 10.33*** | 10.34*** | 10.54*** | 10.33*** |
| | (0.0111) | (0.0207) | (0.0349) | (0.0248) |
| Observations | 142,161 | 142,161 | 142,161 | 142,161 |
| R-squared | 0.703 | 0.718 | 0.853 | 0.862 |
| Year-Month Dummies | No | Yes | Yes | Yes |
| Tract Fixed Effects | No | No | Yes | No |
| Block Group Fixed Effects | No | No | No | Yes |
| Density of Antennas | Yes | Yes | Yes | Yes |
| F Statistic for Joint Significance of Distance | 71.76 | 157.22 | 3.57 | 2.58 |
| P-value for F | 0 | 0 | .03 | .08 |

[a] Also included in each regression are: bedrooms, full bathrooms, partial bathrooms, square feet, square feet$^2$, lot size, lot size missing, age, age$^2$, age unknown, fireplace, basement, finished basement, central air, exterior type, roof type, style of home, garage, carport, 1 mile parkway/interstate, 1 mile rail road, 1 mile Ft. Knox.

[b] Standard errors are clustered at the level of included fixed effects.

[c] Density is measured as the the number of antennas located within specified distances from the property.

*** p<0.01, ** p<0.05, * p<0.1

Table A10: Repeat Sales Regression Results Showing the Effect of Towers Only on Property Values Using a Continuous Measure of Distance. Constant Structural Characteristics. Central Kentucky Data, 2000-2011.

| VARIABLES | (1)<br>Δ ln(Sold Price) | (2)<br>Δ ln(Sold Price) | (3)<br>Δ ln(Sold Price) | (4)<br>Δ ln(Sold Price) |
|---|---|---|---|---|
| Δ Distance to Tower | 0.0106*** | 0.0106*** | 0.0103*** | 0.00627*** |
| | (0.00104) | (0.00104) | (0.00106) | (0.00111) |
| Constant | 0.0560*** | 0.0568*** | 0.0625*** | 0.151*** |
| | (0.00308) | (0.00311) | (0.00332) | (0.00525) |
| Observations | 29,886 | 29,719 | 28,387 | 20,976 |
| R-squared | 0.105 | 0.105 | 0.109 | 0.145 |
| All Repeats | Yes | No | No | No |
| Four or Less | No | Yes | No | No |
| Three or Less | No | No | Yes | No |
| Sold Twice | No | No | No | Yes |
| F Statistic | 279.64 | 279.43 | 277.38 | 270.11 |

[a] Standard errors are clustered at the property level.
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table A11: Repeat Sales Regression Results Showing the Effect of Towers Only on Property Values Using a Continuous Measure of Distance. Changing Structural Characteristics. Central Kentucky Data, 2000-2011.

| VARIABLES | (1)<br>Δ ln(Sold Price) | (2)<br>Δ ln(Sold Price) | (3)<br>Δ ln(Sold Price) | (4)<br>Δ ln(Sold Price) |
|---|---|---|---|---|
| Δ Distance to Tower | 0.00977*** | 0.00971*** | 0.00950*** | 0.00600*** |
| | (0.000977) | (0.000979) | (0.000997) | (0.00105) |
| Δ Bedrooms | 0.0783*** | 0.0768*** | 0.0738*** | 0.0619*** |
| | (0.00557) | (0.00554) | (0.00557) | (0.00621) |
| Δ Full Bathrooms | 0.169*** | 0.169*** | 0.169*** | 0.168*** |
| | (0.00791) | (0.00793) | (0.00812) | (0.00896) |
| Δ Partial Bathrooms | 0.104*** | 0.104*** | 0.105*** | 0.110*** |
| | (0.00950) | (0.00951) | (0.00979) | (0.0113) |
| Δ Finished Basement | 0.0210*** | 0.0213*** | 0.0210*** | 0.00978** |
| | (0.00383) | (0.00383) | (0.00393) | (0.00455) |
| Δ Central Air | 0.254*** | 0.255*** | 0.250*** | 0.243*** |
| | (0.00974) | (0.00978) | (0.0100) | (0.0115) |
| Δ Carport | 0.0595*** | 0.0604*** | 0.0558*** | 0.0395*** |
| | (0.0145) | (0.0146) | (0.0148) | (0.0151) |
| Δ Garage | 0.0157** | 0.0155** | 0.0136* | 0.0203** |
| | (0.00771) | (0.00775) | (0.00792) | (0.00898) |
| Constant | 0.0367*** | 0.0374*** | 0.0424*** | 0.122*** |
| | (0.00287) | (0.00289) | (0.00309) | (0.00489) |
| Observations | 29,886 | 29,719 | 28,387 | 20,976 |
| R-squared | 0.203 | 0.204 | 0.205 | 0.231 |
| All Repeats | Yes | No | No | No |
| Four or Less | No | Yes | No | No |
| Three or Less | No | No | Yes | No |
| Sold Twice | No | No | No | Yes |
| F Statistic | 273.83 | 272.79 | 264.5 | 231.46 |

[a] Standard errors are clustered at the property level.
*** p<0.01, ** p<0.05, * p<0.1