Estimation of Airport Infrastructure Capitalization for Land Value Capture Purposes: An Analysis of Denver and Atlanta

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Abstract

Airports are for economic activities and likely affect the value of many resources, including land. We explore the relationship between airport infrastructure and residential land prices in Denver and Atlanta. We use an innovative approach—Local Polynomial Regressions—to separate the value of land from the value of structures at each locally sold property address, and then estimate the impacts of changes in airport infrastructure improvements on land values. In Denver, we find investments in airfields, parking, and intermodal transportation lead to higher land values in the short-run and long-run, while investments in terminals generally have no significant impact or a negative impact (due to congestion) on land values. Due in part to less instability in land prices over the period 2003–2010, these results suggest Denver appears to be the stronger candidate for land value capture than Atlanta. This approach is an important first step in the process of land value capture in Denver.

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Introduction

Funding large transportation infrastructure projects in the current economic and political environment is challenging. One promising financing option worthy of additional consideration is to rely more on value capture, which is an approach that attempts to realize as public revenue some portion of the increase in land value associated with the infrastructure project. A fundamental argument for value capture is because landowners and homeowners often benefit (as indicated by increased property values) from such improvements due to improved access to travel and employment opportunities, they should bear more of the costs of infrastructure improvements. Moreover, value capture for transportation infrastructure has the potential to raise significant revenues that could be used to finance additional infrastructure. If done properly, value capture also would not compromise efficiency. An effective and efficient tax from the revenue collection standpoint is "inescapable", and one way in which to implement an inescapable tax is through land value capture.

With respect to the implementation of a land value tax, two related issues, one political and one economic, are paramount. The political issue is that a base of political support for the tax must be developed and maintained, while the economic issue is that reliable, market-based assessments must be produced on a timely basis. Our paper focuses on the latter issue. Thus, our focus is not on implementing a land value tax *per se*, but rather on providing reliable estimates and highlighting the underlying methodology for generating this essential component for land value taxation.[1]

An obvious, but far from easy, step in implementing value capture is to produce an accurate estimate of the effect of infrastructure on land prices. One approach to obtain estimates of landowners' valuation of airport improvements would be to consider the implied value of land in sales of particular houses (and/or plots of vacant land) near airports, based on the product of the sales price and the ratio of the assessed value of land to total assessed value. After imputing the value of land at all properties sold, it is possible to use regression analysis to assess how changes in the sizes of airport capital stocks between two periods, for instance, have impacted the changes in land values across space over the same time frame, after controlling for other factors that may affect the land values. This estimate would represent the surplus obtained by homeowners or landowners as a result of airport improvements, after controlling for other factors that may have influenced their surplus. Local governments could then tax the land based on the value of the surplus generated from proximity to improved airport infrastructure.

However, the approach using assessed values can be criticized due to the complex interaction between land values and the values of improvements, an interaction that may not be included in

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[1] For a summary of using value capture for financing transportation projects, see reports on this issue for the Minnesota legislature at: www.cts.umn.edu/Research/ValueCapture.

assessed values.[2] We introduce an alternative approach that isolates the land values more precisely, and apply it to properties in Denver, over the period of 2003–2010, using housing data that delineates the sales price, and various housing characteristics.[3] We also analyze properties in Atlanta over the same period, but due in part to the sharp drop in the land price index in the years 2008 through 2010, as well as possibly the need to consider additional houses sold in the Atlanta area, the land value estimates and the resulting analysis of their determinants are very unstable. We examine airport spending data available from the Federal Aviation Administration in several categories. Such an approach would be a promising first step in the direction of achieving value capture at residential properties near airports (or other transportation infrastructure), possibly leading to a new revenue source that could help finance additional airport infrastructure. However, caution should be exercised when attempting to use this approach if the time period under analysis includes sharp decreases in land prices due to a real estate "bust".

The major contributions of this paper include our application of the Local Polynomial Regression model to separate the value of land from the value of structures. Second, our use of this land value data enables us to determine the impacts of changes in airport infrastructure investment on land values, which is important for the purpose of extracting land value from property owners. Third, more generally, our work contributes to the literature of the impacts of infrastructure improvements on housing prices.

The body of the paper consists of several sections. The next section is a literature review. This review is followed by a summary of our estimation procedure for land prices, which is a semiparametric approach developed by Clapp (2004), and the resulting land values. The following section describes the details of our data. In the next section, the determinants of the land values are examined. The key determinant is airport infrastructure. A summary of key results and several questions for further research completes the paper.

Literature Survey

Housing prices (i.e., the total price that includes land and structures) in the U.S. experienced a dramatic increase in the years leading up to 2008, followed by a substantial "bust" in the subsequent years.[4] Cohen, Coughlin and Lopez (2012) describe how some regions of the U.S. faced more of a downturn than others. Figures 1a and 1b below depict quarterly housing prices in two major U.S. cities in different geographic regions—Denver and Atlanta—in the years 2000 through 2012. While the rise in housing prices is comparable from 2000 to their respective peaks, the bust in Atlanta was far more pronounced than in Denver. In fact, even as of February 2013, housing prices in Atlanta were less than in January 2000. Meanwhile, Denver housing prices were, on average, 38 percent higher.

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[2] In most jurisdictions in the US, property is taxed on the basis of total value, so the assessor has little incentive to be careful about separating land value and structure value.

[3] We have chosen this time frame due to the availability of airport infrastructure investment data over this period.

[4] See Cohen, Coughlin, and Lopez (2012) for details.

During roughly this same time period, there has been substantial variation in airport infrastructure investment, as well as depreciation, at the airports in Denver and Atlanta. The past investment levels, net of depreciation, can be used to obtain a stock of airport infrastructure for a variety of airport infrastructure categories. These stocks of infrastructure are presented in Tables 1c and 1d for Denver and Atlanta, over the period 2003 through 2010.

A large literature examines how and to what extent transportation infrastructure becomes capitalized into housing prices, including McMillen and McDonald (2004), Weinberger (2000), and Forest, Glen, and Ward (1996). These papers use a hedonic pricing approach to assess the impacts of the transportation infrastructure on housing prices (or commercial rents, in the case of Weinberger). Gatzlaff and Smith (1993) use both a repeat sales approach and a hedonic housing prices approach to examine the effects of a new rail line in Miami, and find that it had only a minimal impact. However, none of these papers directly address the issue of transportation infrastructure capitalization by distinguishing the distinct impacts on land and structures values.

During a period with wide fluctuation in housing prices as well as improvements in public services such as airport infrastructure, it could be helpful for policy makers to isolate the impacts of improvements in airports on land values. This capitalization could provide the basis for land value capture based on airport improvements. Chapman et al. (2009) examine the feasibility of land value taxation for financing transportation infrastructure in Utah, and find that in addition to being a non-distortionary form of taxation, the land value tax could generate significant revenue and would be relatively straightforward to administer. Cohen (2012) summarizes the ideas behind value capture at airports. He describes that economic theory underlying how value capture implies improvements to airports become capitalized in land values. These land rents can be taxed with a land value tax, and this tax is preferable because it is non-distortionary. However, in order to achieve land value capture in practice, it is necessary to obtain estimates of land separately from the improvements to land. This is one of a number of practical issues involved in estimation of transportation infrastructure capitalization into land values.

Longhofer and Redfearn (2009) examine how one might in practice disentangle the value of land from the value of structures on the land. Longhofer and Redfearn argue that land and structures are inseparable. Their argument (mostly contained on pp 4–6) is that houses within a neighborhood are fairly homogeneous. For example, it may not be possible to buy a small house on a small lot in a neighborhood with much larger houses. They give an example where the supply of pools cannot adjust to the demand within a given neighborhood, so pools are priced “too high” in some neighborhoods. They use vacant land on the periphery of a city, along with the estimation technique of locally weighted regressions, to estimate the values of land throughout the city. One drawback of their approach, however, is that it requires data on vacant land sales to derive the land values for all properties.

As an alternative, Clapp and Salavei (2010) implement an “option value” approach that addresses the problem from a different perspective than Longhofer and Redfearn: existing structure relative to optimal structure at any time will influence the value of the land. The costs of adjustment are high, so it takes a long time to reach the trigger point to redevelop. The costs of rebuilding to a new optimal level are the cost of construction and the sacrificed rents from the existing structure (i.e., this is an exchange option). Thus, a house with specific characteristics, such as age, layout, and size, will have implicit characteristic prices that vary with the land value.

Identical to the approach we utilize, Clapp (2004) uses a local polynomial regression model (LRM) to disentangle land and structure prices by holding constant structure value and extracting the associated land value. Similar to Longhofer and Redfern (2009), a locally weighted regression is part of the research design.

In the context of the effect of transportation infrastructure, another issue is the timing of the capitalization effect. Clearly, market prices respond to many types of information, so price adjustments may occur at the time of the expansion announcement. What is not clear is the time path of the adjustment process. Prices may not adjust fully until the investments are in place or even later if the potential effects of the investment, such as new services and ease of use, are initially unclear.

Jud and Winkler (2006) examine the impact of announcement of construction of a new hub airport, which is expected to lead to greater noise, on housing prices in Greensboro, NC. They find that this post-announcement effect is nearly a 10 percent reduction in housing prices within 2.5 miles from the airport. Agostini and Palmucci (2008) found an announcement of new transit station construction led to an increase in nearby housing prices ranging between 3% and 8%. Similarly, McMillen and McDonald (2004) found the housing market began adjusting to a new rail line before the construction was completed. Clearly, it will be important in our context to consider both the announcements of expansions as well as the actual construction expenditures and dates, by examining first and second differences around the actual year of the expenditure.

Approach and Analysis

First, we consider the problem of obtaining the land values separately from structure prices. The Clapp (2004) and Clapp and Salavei (2010) “option value” approach is followed here. We are interested in the variation in the bundle with changes in the value of the location due to airport expansion. We can consider this change to be a change in land value—as improved. LRM is designed to capture this change, holding constant for the base level of structure value. It is this as-improved property value that is taxed. Vacant land (option to scrape is exercised, or an irrevocable decision to scrape) should vary by the same amount. Therefore, taxing the bundle increment has the same effect as taxing the increment in vacant land value.

After generating land prices, we use the estimated land values as part of an interpolation to produce estimated land values for residential properties for the years in which the property was not sold. Given the land values, we explore how they are affected by airport infrastructure. We address the timing issue discussed earlier by examining long-term as well as short-run effects of changes in the value of various categories of airport infrastructure stocks on land values.

Methodology

This section summarizes the local regression model (LRM) used to estimate a surface of land values over time; see Clapp (2004) for more details. The choice of LRM is motivated by the observation that structures are reproducible at current construction costs whereas location value (the value of the right to build a single family residence at a given location) varies substantially across space and time. By separating the structure and land components we can estimate the variation in location value over time, and correlate it with airport expansion events.[5]

We begin with a standard hedonic model, a parametric method for finding implicit prices for each element of the vector of housing characteristics (structure and location), and a price index independent of these characteristics. Regress the log of sales price (*lnSP*) on a vector of house structure characteristics (Z), locational characteristics (S), and time (*t*) which is represented here in the form of annual time dummies, Q_t:

$$ln\mathrm{SP}_{\mathrm{it}} = \gamma_0 + Z_i\alpha + S_i\beta + \gamma_0 Q_0 + \gamma_1 Q_1 \ldots + \gamma_T Q_T + \varepsilon_{it} \qquad (1)$$

where ε is typically an iid noise term that is assumed to be normally distributed for the purposes of hypothesis testing.[6]

The cumulative log price index for a standard house in the area where the data were collected is measured by the parameters on the annual time dummies, γ. The assumption is that the parameters on structure and location are constant over time. Since they are not, we are measuring the average implicit prices, α and β over the time interval *T*. Thus, any change over time is forced into the estimates of the γ parameters; they can be considered an approximation to a pure time component that shifts the constant of the regression, γ_0.

The LRM is designed to allow substantial nonlinearity in the spatial and time dimensions: it fits a value surface at each point in time as an alternative to estimating the set of parameters in equation (1). The LRM views price index and value surface estimates as descriptive exercises that are not designed to test hypothesis about parameters. Writing the model as follows emphasizes the nonlinear and nonparametric aspect of the LRM:

$$ln\mathrm{SP}_{it} = f(Z_i, S_i, t_i) + \varepsilon_{it} \qquad (2)$$

We allow the function *f( )* to be nonlinear because local house prices rarely move in a straight line over time and a nonlinear spatial pattern is well known. These nonlinearities, as well as the descriptive purpose of the model, make nonparametric smoothing regressions an ideal tool.

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[5] Davis and Palumbo (2008) develop a model decomposing property value into structure and land components, and they use this model to find significant changes in land value over time and across metropolitan areas. They depend on subtracting the cost of construction from sales prices, whereas we use the implicit value of the structure. The Davis and Palumbo approach can be viewed as a robustness check.

[6] The log of sales price is the dependent variable because logarithms control for heteroscedasticity` and some nonlinearity. Using sales price, SP, instead would cost degrees of freedom; See Hastie and Tibshirani (1990), pp. 52-55 for a discussion of degrees of freedom for smoothing models.

LRM estimation methods can be introduced by imagining that a number, q, of identical houses trade at a given point in space and time, denoted by the fixed vector (**z**$_0$, **s**$_0$, t$_0$). Then, an obvious way of estimating equation (2) at the fixed point would be to average those prices:

$$\hat{f}(\mathbf{z}_0, \mathbf{s}_0, \mathrm{t}_0) = \frac{\sum_{i=1}^{q} ln\mathrm{SP}_{it_0}}{q} - \frac{\sum_{i=1}^{q} \varepsilon_{it_0}}{q} \qquad (3)$$

The error term results from negotiation between heterogeneous buyers and sellers. Since the average error term will tend to zero as the sample size gets large, we will have a consistent estimator of a point on the value surface at the given point in time.

Actual sales prices are spread out in space and time as well as over the range of housing characteristics, **z**. If the data were densely distributed over these characteristics, then we could average prices that are "close to" any particular point in characteristic space (**z**$_0$), physical space (**s**$_0$) and time (t$_0$). This averaging process is very much in the spirit of nonparametric smoothing.

Nonparametric smoothing implements this local averaging idea by down-weighting observations that are more distant from the fixed point:

$$\hat{f}(\mathbf{z}_0, \mathbf{s}_0, \mathrm{t}_0) = \sum_{i=1}^{q} \frac{K_h(\cdot) ln\mathrm{SP}_{it_0}}{\sum_{i=1}^{q} K_h(\cdot)} - \frac{\sum_{i=1}^{q} \varepsilon_{it_0} K_h(\cdot)}{\sum_{i=1}^{q} K_h(\cdot)} \qquad (4)$$

where the weighting function, $K_h(\cdot)$, is defined such that greater distances (e.g., larger values for S$_i$ – **s**$_0$) imply lower values for K; h is bandwidth, a set of parameters that govern the selection of points "close to" the target vector.[7]

Bandwidth selection is a trade-off between high variance (bandwidth is too small) and high bias (bandwidth is too large). This paper uses a cross validation method for bandwidth selection: See Wand and Jones (1995, Chapter 4). Locally adaptive bandwidths are allowed by increasing bandwidth until 20 observations are within one bandwidth of the fixed point.

Equation (4) is a special case of local polynomial regression (LPR). Given a specific point in space and time, **x**$_0$ = (**z**$_0$, **s**$_0$, t$_0$), the data, **X**$_i$ = (**Z**$_i$, **S**$_i$, t$_i$) and Y$_i$ = *ln*SP$_i$. Local polynomial regression now takes the form of equation (5):[8]

$$Y_i(\mathbf{x}_0) = \beta_o + (\mathbf{X}_i - \mathbf{x}_0)\beta_1 + (\mathbf{X}_i - \mathbf{x}_0)^2 \beta_2 + \ldots + (\mathbf{X}_i - \mathbf{x}_0)^p \beta_p + \varepsilon_i \qquad (5)$$

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[7] Equation (4) is the well-known Nadaraya-Watson (NW) smoother. See Clapp (2004) for details on the choice of the kernel weighting (i.e., density) function. Experts in this field have found that the choice of bandwidth is much more important than the choice of a kernel density function.

[8] The exponents in equations (5), (6) and (8) are taken element-by-element.

Here, the β_j (j=1,…,p) are column vectors with number of elements equal to the columns of $\mathbf{X}_i$: β_0 is a scalar.[9] Note that, when $\mathbf{X}_i$ equal $\mathbf{x}_0$ then equation (5) reduces to β_0, the parameter of interest. Thus, LPR fits a surface to the Y-values conditional on the values of **x** given by $\mathbf{x}_0$: E.g., **x** is a rectangular grid of equally spaced points that span the data; the level of Y is estimated conditional on each knot of the grid.

Kernel weights are applied when estimating equation (5):

$$\mathrm{MiN}(\hat{\beta}) \sum_{i=1}^{n} \{Y_i - \beta_0 - \ldots - (\mathbf{X}_i - \mathbf{x}_0)^p \beta_p\}^2 K_h(\mathbf{X}_i - \mathbf{x}_0) \tag{6}$$

where the weights are applied to each of the variables including the constant term (the vector of ones). The only difference between the weights in equation (6) and those in equation (4) is that time has been entered as a vector rather than a scalar.[10] Thus, the parameters estimated using equation (6) can be defined as follows:

$$\hat{\beta}(\mathbf{x}_0) = (\mathbf{X}_{\mathbf{x}}^{\mathbf{T}'} W_x \mathbf{X}_x)^{-1} \mathbf{X}_x^{T'} W_x Y \tag{7}$$

$$\mathbf{X}_x = \begin{bmatrix} 1 & \mathbf{X}_1 - \mathbf{x}_0 \cdots (\mathbf{X}_1 - \mathbf{x}_0)^p \\ \vdots & \vdots \quad \ddots \quad \vdots \\ 1 & \mathbf{X}_n - \mathbf{x}_0 \cdots (\mathbf{X}_n - \mathbf{x}_0)^p \end{bmatrix} \tag{8}$$

$$W_x = diag\{K_h(\mathbf{X}_1 - \mathbf{x}_0), \ldots, K_h(\mathbf{X}_n - \mathbf{x}_0)\} \ . \tag{9}$$

This regression is repeated for each point on the $\mathbf{x}_0$ grid.

LPR is a weighted OLS regression at the point $\mathbf{x}_0$, so we can test hypotheses on the $\hat{\beta}$'s by assuming that they are multivariate normal with the following covariances:

$\left(Var - Cov(\hat{\beta})\right) = \left(\mathbf{X}_x^T W_x \mathbf{X}_x\right)^{-1} \mathbf{X}_x^T W_x \mathrm{V} \mathrm{W}_x \mathbf{X}_x \left(\mathbf{X}_x^T W_x \mathbf{X}_x\right)^{-1}$,where V is a diagonal matrix of variances for ε_i.

The treatment of time is much more flexible in equation (5) than it would be in the OLS model, equation (1). LPR treats time as an addition to the spatial dimension: that is, we grid time as finely as the data permit at each point in space. For example, to estimate the value function at 10 points in time, and at each point of a 30x30 spatial grid, we need 9,000 regressions. Each estimator gives high weight to observations that are nearby in space and time and lower weight to those that are farther away.

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[9] The parameters other than β_0 allow for curvature around $\mathbf{x}_0$; a weighted average of neighboring points, equation (4), would ignore curvature. Also, comparing equations (6) and (3) show how LPR takes local averages.

[10] The metric for time is different from that for space (and also different for structural characteristics). Cross-validation (CV) is used to select optimal bandwidths: If CV indicates that observations more distant in space should receive more weight, then a larger bandwidth will be chosen in the spatial dimension. This addresses a concern raised by Pavlov (2000).

The semi-parametric LRM model enters because of the "curse of dimensionality." As a practical matter, there would typically be six or seven variables in the **X** matrix. If all were represented by even a coarse grid, the data would typically be sparse near any point. The semi-parametric solution assumes linearity for the parameters on all the housing characteristics in the matrix **Z**.[11] In the LRM method, an LPR model is used to estimate these coefficients allowing for conditional on the location of the house. This approach addresses the concerns of Longhofer and Redfearn (2009) and provides statistical independence between the estimated coefficients on Z and the nonlinear part of the model. Then the residuals from this regression can be fit with an LPR model.

Following this logic, the LRM method begins by estimating equation (1), then revising the $\hat{\alpha}$'s to assure independence from the land value estimates.[12] Then, partial residuals are taken by subtracting the estimated value of structural characteristics:

$$partres_{it} = lnSP_{it} - Z_i \hat{\alpha} \tag{10}$$

where *partres* is the partial residual from equation (1).

The nonparametric part of the LRM model is:

$$partres_{it} = q\left(S_i, t_i\right) + \varepsilon_{it} \tag{11}$$

where S_i is now defined as the latitude and longitude for house i. Typically, LPR estimation of equation (11) can deal with the two spatial dimensions and the time dimension without substantially increasing the standard error of the *q(.)* estimate. From another perspective, the method requires sufficient density of transactions near the given target point, $\left(S_i, t_i\right)$.[13] Estimation methods for standard errors reveal any problem with lack of data.

To summarize, the purpose of the LRM is to estimate location value over time, $q\left(S_i, t_i\right)$, equation (12). Since we subtracted an average value of structural characteristics, $Z_i \hat{\alpha}$ estimated so as to require independence from $q\left(S_i, t_i\right)$, the LRM estimate may be taken as a reasonable approximation to location value.[14]

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[11] Of course, a nonlinear relationship (e.g., with building age) might be more appropriate. The point here is to focus on the highly nonlinear space-time relationships.

[12] See Clapp (2004) for details on methods for estimation of $\hat{\alpha}$.

[13] A problem with temporal aggregation in the standard hedonic method - the bunching of transactions within the quarters, equation (1) - is handled nicely by the kernel weighting scheme applied to equation (13).

[14] However, it may be objected that location value should be estimated as property value less construction costs, as suggested by Davis and Palumbo (2008). To get to this quantity, one would add back $Z_i \hat{\alpha}$ and then subtract

Once we obtain the land values, holding constant for structure values, we use these land values to assess the impacts of airport expansions on land values. The unit of observation is the individual house transaction (not repeat sales). Specifically,we consider major improvements such as terminal expansions, airfield improvements, parking structures, roads/transit/rail, and all other expenses, to construct airport capital stocks for each of these categories. These capital stocks control for depreciation. We identify the impact of a major improvement in year t off of change from before to after the event. Specifically,

- We expect distance from the airport to attenuate the effect.

- We expect long run changes (more than one year before and after changes in the airport capital stock) to be different from short-run effects (one year or less before and after). See Clapp and Ross (2004). The effect should build up to a larger total over a longer term, if the cause is a permanent increase in the number/frequency of airline service.

We also initially include cross-sectional dummies to control for unobservables. Also, those professional jobs requiring a lot of travel might locate closer to the airport, especially after expansion. However, we don't have the identifying demographic groups that Clapp and Ross (2004) had. For our paper, a strategy for allowing sorting is to allow sufficient lags after airport expansion for those valuing this to bid up the price of housing benefiting from the expansion. We evaluate increasingly long intervals around the expansion event, as described above, to deal with the lag issue.

While we would also be able to control for any increase in airport noise using methods similar to earlier work by Cohen and Coughlin (2008), there are few houses in the noisy zones. Also, any heterogeneity due to noise can be captured through our individual-level Fixed Effects (FE). Since our model is based on the FE, there is also little point in trying to collect demographics at the CBG level. The reason for individual transactions is that houses within the CBG will differ in their access to the expanded airport. By lining all the transactions up around the expansion events (time zero is event date, regardless of calendar date), and including calendar year FE along with the individual level FE, we control for omitted variables other than the expansion. However, we do not have enough "events" in enough MSAs to do the statistical tests used in event studies in the finance literature. The most important explanatory variables are distance from the airport interacted with the amount and type of expansion. It may also be the case that some expansions don't increase congestion but only make the terminal facilities more attractive.

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construction costs. An approximation to construction costs can be obtained by assuming that they are invariant within the metropolitan area and that they change slowly over time as the costs of material and labor change. With these assumptions, the level of construction costs at time zero is the same for all houses in the city. One can use the Marshall Valuation Service (MVS) to approximate this level. Then percentage changes over time can be approximated by using a construction cost indexes such as those published by Engineering News-Record (ENR, http://enr.construction.com/economics/). With these adjustments, location value is estimated by:

$$\hat{q}\left(\mathrm{S}_i, t_i\right) + Z_i\hat{\alpha} - C_{it}$$

where C_{it} is an estimate of construction costs for house *i* at time *t*. This procedure can be considered as a robustness check.

For our estimation of effects of infrastructure stocks on land values, we estimate the following model after obtaining extrapolated land values for each house in each year (see Appendix for description of the extrapolation approach):

$$L_{i,t} = c_0 + c_1 *A_{1,\,i,t} + c_2 *A_{2,\,i,t} + c_3 *A_{3,\,i,t} + c_4 *A_{4,\,i,t} + c_5 *A_{5,\,i,t} + \alpha + \tau + \varepsilon_{i,t} \qquad (12)$$

In this model, $L_{i,t}$ is log of land value, normalized by log of acres[15] for property i in year t; $A_{1,\,i,t}$ through $A_{5,\,i,t}$ represent airport infrastructure stocks for property i in year t for airfields, terminals, parking, roads/rails/transit, and "other", respectively; $A_{1,\,i,t}$ through $A_{5,\,i,t}$ are weighted by the distance from house i to the airport; α and τ are individual and time fixed effects, respectively; and $\varepsilon_{i,t}$ is an iid error term with mean zero, constant variance and zero covariance across observations; and for Denver, i=1, 2,…, 178,731; t=2003, 2004,…, 2010.

To compare the short-run versus long run impacts on land values of changes in airport infrastructure, we employ a differencing approach, which leads to the following model:

$$\Delta_d L_{i,t} = c_1 *\Delta_d A_{1,\,i,t} + c_2 *\Delta_d A_{2,\,i,t} + c_3 *\Delta_d A_{3,\,i,t} + c_4 *\Delta_d A_{4,\,i,t} + c_5 *\Delta_d A_{5,\,i,t} + \theta + \Delta_d \varepsilon_{i,t} \qquad (13)$$

where Δ_d is the dth difference, d=1,2,3. When d=1, this represents the short-run impacts of changes in airport infrastructure on land values; d=2 represents the medium-term impacts; and d=3 represents the long-term impacts. Note that the differencing causes the cross-sectional fixed effects to drop out, and there are a new set of time-specific fixed effects, θ, which includes a constant (intercept) term.

Denver Analysis

Figure 1a depicts housing prices in Denver in the years 2000 through 2012. During the period of our data sample for airport infrastructure investment (2003 through 2010), housing prices rose by about 8% in the boom years (2003 through 2007), while they fell by about 7.4% during the bust years (2007 through 2010). There were somewhat larger fluctuations in land prices, with a steadily decreasing land price from Davis and Palumbo (2008), as can be seen in Figure 1c. Specifically, between 2003 and 2007, land prices in Denver fell by 11.5%, while during the years 2007 through 2010 land prices fell by 30.7%. This trend can be seen in Figure 1c, which covers the broader period of 2000 through 2010. It is noteworthy that land prices rose dramatically between 2000 and 2003, before the steady subsequent decrease in land prices.

Descriptive statistics for the housing data are presented in Table 1a for Denver. There were 178,731 sales observations for single family residential homes that sold between 2003 and 2010 in Denver. The average house in Denver had 3 bedrooms, with approximately 2 full baths and 0.18 half-baths. The average sale price was approximately $280,000, and was located about 19.3 miles from the airport. The closest house was 4.8 miles from the airport while the furthest house was 56 miles away. Figures 2a and 2b show the locations of the Denver home sales relative to the airport for the years 2003 and 2010, respectively.

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[15] There is evidence that land values increase with the square root of lot size, so the fact that we are using logs is important since it prevents excess acreage from having the same effect on value as the building pad.

The annual Denver International Airport capital stock data for 2003 through 2010 are listed in Table 1b. As can be seen by examining the data for each category (airfields, terminals, parking, intermodal transportation, and other) in each year, there is variation in these capital stocks over time and across different categories. We used investment data to construct capital stocks for each of these categories of airport infrastructure, using the perpetual inventory method. Specifically, we deflated the investment series using a national deflator for government investment obtained from the 2013 Economic Report of the President, and the initial (or seed) value for the capital stock for each category is obtained as the average of the investment data for the years 2001 through 2004, multiplied by the estimated service life for each category of investment. The depreciation rate was assumed to be the inverse of the service life, and the capital stocks followed a straight line depreciation path. Additional details on the capital stock construction can be found in the data appendix. Once we constructed the capital stocks, our approach was to assign a capital stock value for each category to each single family residence sold, by weighting the capital stock by the property's inverse distance from the airport. Thus, properties more distant from the airport are viewed as having less airport capital.

We examine how land prices, obtained for each SFR sold in 2003–2010, are impacted by investment in airport infrastructure over time, for Denver and Atlanta. After implementing the LPR approach to obtain land values for each of these cities, and then interpolating to obtain a land value for each house in each year of our sample, we regress (for each city separately) the log of land values (normalized by log of acres) on a constant, on each of 5 categories of airport infrastructure capital stocks (airways, terminals, parking, roadways/railways, and other), as well as a set of cross-sectional and time fixed effects.[16] In these regressions, we normalize the capital stocks by each house's inverse distance to the airport (and a robustness check, we also normalize by inverse of distance-squared, which has little impact on the results). The distance is calculated as the Euclidean distance from the house to the airport using latitude and longitude data for each point.

Table 2 presents the hedonic regressions results for Denver. After controlling for year effects, it is noteworthy that all housing characteristics variables that enter linearly have the expected sign.

Tables 3, 4, 5, and 6 present the second-stage regressions of the log of land values on the various infrastructure categories for Denver (weighted by the inverse of the distance from the airport). First, Table 3 is the fixed effects estimation, with one dummy for each location. We find that higher capital stocks in airfields, parking, and roads/rails/transit all lead to higher land values. Higher capital stocks for terminals, and "other" airport infrastructure, have no significant effect on land values. An alternative approach is to consider first-differences. In this specification, the parameter estimates on the infrastructure variables are considered to be short-run effects.

Table 4 presents these first-difference regression results, and once again, the airfields, parking, and road/rails/transit capital stocks have a positive and significant effect on land values. Also, the terminals capital stock is negative, but, similar to the fixed effects results, is insignificant. The

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[16] Figures 3a and 3b show quintiles for the interpolated land values in Denver in the years 2003 and 2010. Due to the fact that the Atlanta land price index approaches zero beginning in 2008, we omit the corresponding land value figures for Atlanta.

"other" variable is also negative, but, contrary to the fixed effects regression results, is insignificant.

The second-difference results, presented in Table 5, can be considered the medium-term effects. Once again, similar to the results in Table 3, the airfields, parking, and roads/rails/transit variables are positive and significant, while the terminals and "other" capital stocks are positive but insignificant. The medium-term effects of most types of infrastructure on land values are similar to the short-run effects.

The long-run effects (third-difference) are presented for Denver in Table 6. In the long-run, both airfields and roads/rails/transit have no significant effect on land values, while terminals have a negative and significant effect, while "other" has a positive and significant effect.[17] The negative and significant coefficient on the terminals variable in the third difference analysis may be due to congestion arising from terminals that have grown in size over time.

Atlanta Analysis

The annual Atlanta International Airport capital stock data for 2003 through 2010 are listed in Table 1c. The various categories of airport infrastructure (airfields, terminals, parking, intermodal transportation, and other) vary over time and across different categories. Although we account for depreciation, a primary driver of the variation over time is changes in the investment flows. We used investment data to construct the capital stocks for each of these categories of airport infrastructure, using the same approach as for Denver. Additional details on the capital stock construction are in the Data Appendix.

Figure 1b depicts housing prices in Atlanta in the years 2000 through 2012. During the period of our data sample for airport infrastructure investment (2003 through 2010), housing prices rose by about 17% in the boom years (2003 through 2007), while they fell by about 30% during the bust years (2007 through 2010). As we describe below, land prices were the primary driver behind this decline.

Specifically, between 2003 and 2007, land prices in Atlanta fell by 12.5%, which was comparable to the 11.5% decline in Denver. But in the second half of 2007, the Lincoln Institute's land price index for Atlanta begins to drop more steadily (at a value of 0.80). During the years 2007 through 2010 Atlanta land prices fell by more than 99%. This trend can be seen in Figure 1c, which covers the broader period of 2000 through 2010. There was roughly a 20% land price rise in Atlanta between 2000 and 2003, before the beginning of the precipitous drop in land prices.

For Atlanta, we attempted to estimate the LPR model along with the first and second difference analysis, but find the signs and magnitudes of the estimates were implausible. We attributed this

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[17] As an alternative, the announcements of expansions, coupled with their values, might be an appropriate approach to organize the expansion data. We are unable to implement such an alternative because the airport investment data we obtained from the Federal Aviation Administration does not distinguish between the announcement of expansions and the time of expenditures associated with the expansions.

to the fact that the sample for Atlanta includes the years 2008 through 2010, when the Atlanta land price index approached zero. We also tried controlling for changes in land prices through an alternative approach, but the results for both cities were not substantially different in terms of the signs and magnitudes of the parameter estimates. This approach was to calculate the average log of land price in each city in each year, divide this average price by the average of the log of acres, and then multiplying this number by each of the corresponding time dummy parameter estimates from each city's hedonic regression. Then, for the interpolated land value per log of acres in a given year, we subtracted the product of the time dummy parameter in that year times the ratio of the log of land price to the log of acres in that year, to obtain an inflation-adjusted land price. This land price drop had a dramatic effect on the real land value estimates, making them much larger than they would be had Atlanta not experienced such a dramatic drop in land values.

Another possible explanation for the implausible Atlanta results (perhaps in addition to the land price drop) could be related to the housing sales data. If we were to add additional home sales surrounding the airport, perhaps this would lead to more plausible results. However, we are skeptical that this would completely solve the problem. When calculating the real price of land, the proper approach is to divide the interpolated land value by the price index, so for the years when the land price index approaches zero the real land prices explode.

Unfortunately, this is one potential drawback to performing this type of analysis on a city such as Atlanta during a period of a land price bust.

Conclusion

We implement a Local Polynomial Regression framework to estimate land values for single family houses sold in Denver between 2003 and 2010. We then use these land value estimates to assess how various types of airport infrastructure investment affect land values. We find for Denver that investments in airfields and parking lead to higher land values in the short-run and medium term, while most other types of airport investments have little effect on land values. Terminals in Denver have an insignificant effect on land values in the short-run, but in the long-run terminals have a negative effect on land values, perhaps due to additional congestion arising from bigger terminals. The results for Atlanta are unstable—possibly because of the tremendous drop-off in land values during the period of our sample—and therefore Atlanta is a much less promising candidate for implementing value capture near airports.

These findings raise the question of when land value capture techniques might be appropriate, and how they should be implemented. The results demonstrate the difficulties that would be present when attempting to implement value capture during a period of a pronounced boom and bust. In a boom, the price of land is too high relative to its fundamental value, so eventually there is a bust, leading to a dramatic drop-off in land prices relative to one of the boom years. Accordingly, the relatively dramatic land price swings in Atlanta that were much more pronounced in Denver illustrates how challenging it might be to potentially implement value capture in an environment of boom and busts. Among these two cities, Denver would be the more promising city to consider implementing land value capture near airports. Although there were fluctuations in land prices in Denver, they remained plausible in the bust years, and we believe this is reflected in the results of our differencing analysis. Further research could explore additional techniques to implement value capture in such complex environments of sharply declining land values. Perhaps gathering additional data could help, although this would be a more promising approach when the extra data spans over years when land prices were increasing or stable. Unfortunately the time period of our study (2003–2010) was limited by the availability of airport infrastructure data from the FAA.

While the focus of this paper has been on measuring the extent to which airport investments become capitalized into land values, another topic for future research would be how to implement value capture when it is found that airport improvements generate land rents. An additional issue worth considering is how to handle investments that lead to lower land values. For instance, if in the long-run additional terminal investment increases traffic along roads in towns near the airport, leading to lower land values, does that imply negative land taxes would be appropriate in such circumstances? This is a question that has been raised by Ingram and Hong (2012), and it is deserving of additional consideration.

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Data Appendix

Capital Stocks

We use the perpetual inventory method to obtain estimates of capital stocks. We assume the depreciation rate = 1/service life, where service life of airport terminals and airfields = 25 years; service life of parking = 40 years; service life of roads/rail/transit = 44 years; service life of “other” = 25 years.

The 25 year number for airfields and terminals came from airports council international, used in Cohen and Morrison Paul (2003).

The highways and streets service life: 60 years (0.0152); state and local railroad equipment: 28 yrs (0.0590); For the roads, rail, and transit variable, we take the average of these 2 service lives and use 44 years service life. Source: http://www.bea.gov/scb/account_articles/national/0797fr/table3.htm:

Parking: http://www.chamberlinltd.com/extending-the-service-life-of-parking-structures-a-systematic-repair-approach/

Initial capital stocks are average of 2001, 2002, 2003, and 2004 expenditures, times the service life for that category

Land Price Indexes

We interpolated land values for all years for each house, using a method devised by Clapp (2004) and subsequently modified by Brett Fawley and us. Details are available from the authors upon request.

Subsequently, we deflated the land values and then normalized them by log of acres.

Land price indexes: from Q2 for each MSA (Denver and Atlanta), from Lincoln Institute of Land Policy land price indexes (residential land); www.lincolninst.edu

Figure 1a—“Boom” and “Bust” Single Family Home Sales Prices, Denver

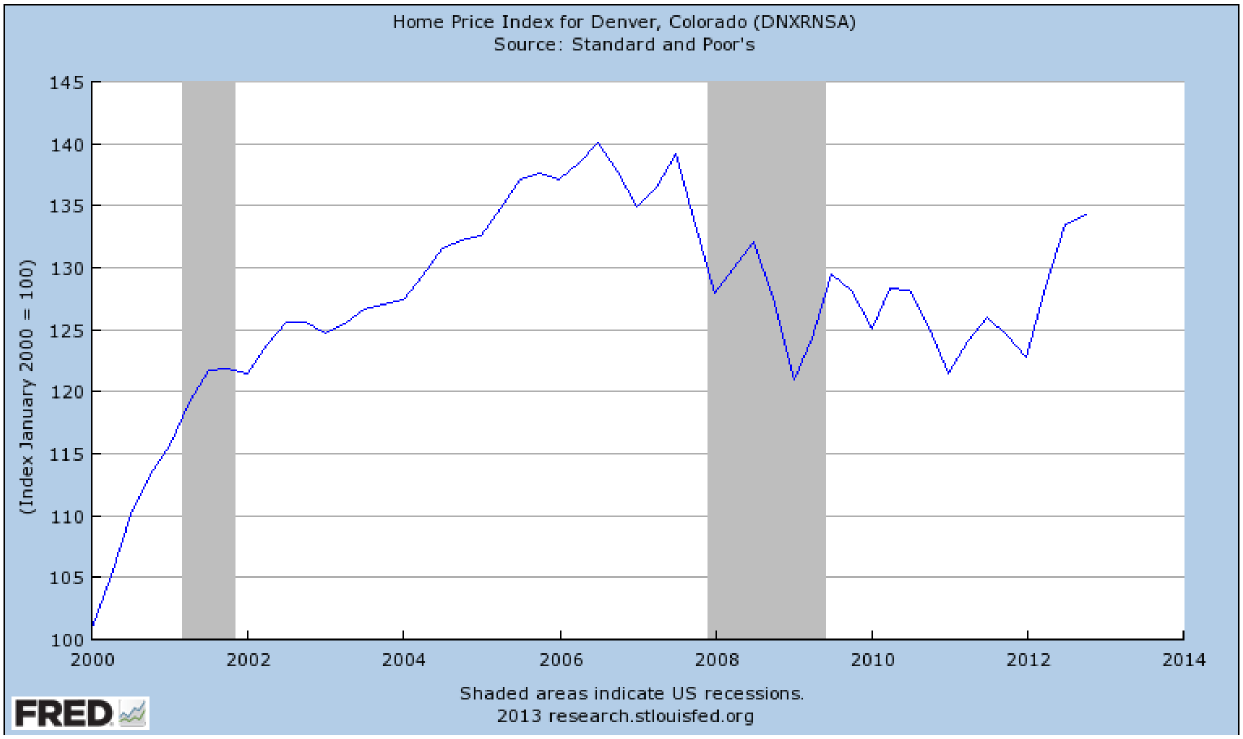


Figure 1b—“Boom” and “Bust” Single Family Home Sales Prices, Atlanta

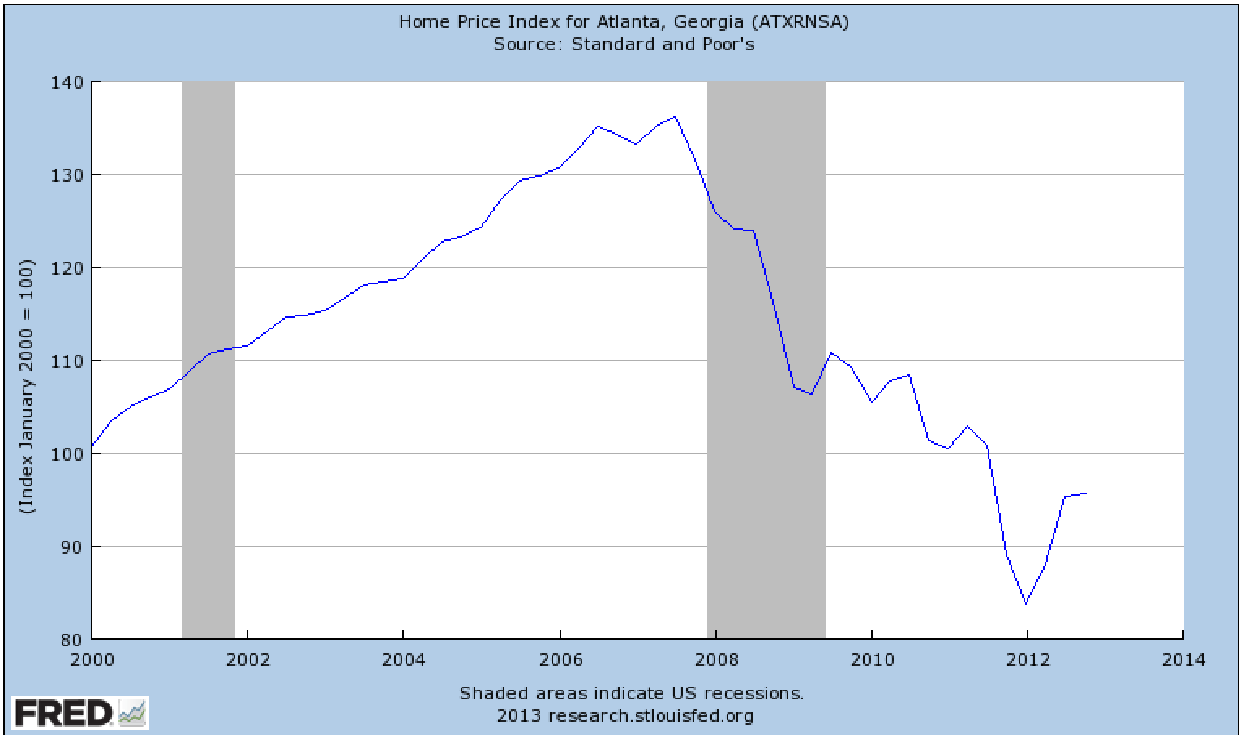


Figure 1c: Land Price Indexes, Denver and Atlanta, 2000:1 - 2010:4

(source: http://www.lincolninst.edu/subcenters/land-values/metro-area-land-prices.asp)

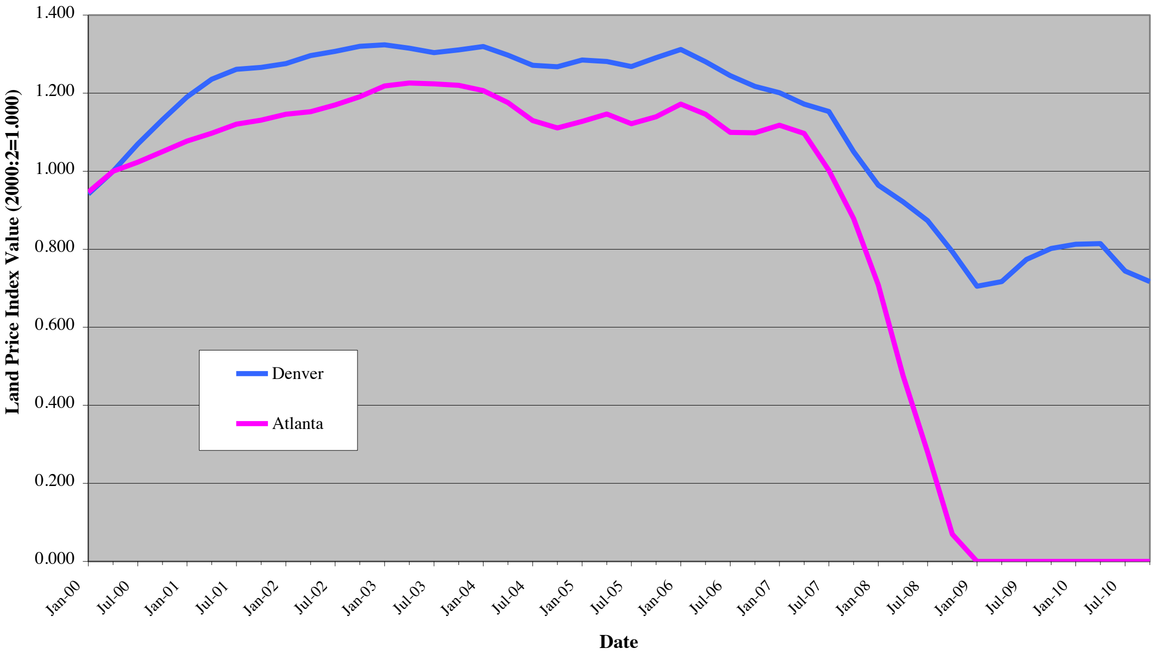


Figure 2a—Single Family Home Sales in 2003 for Denver

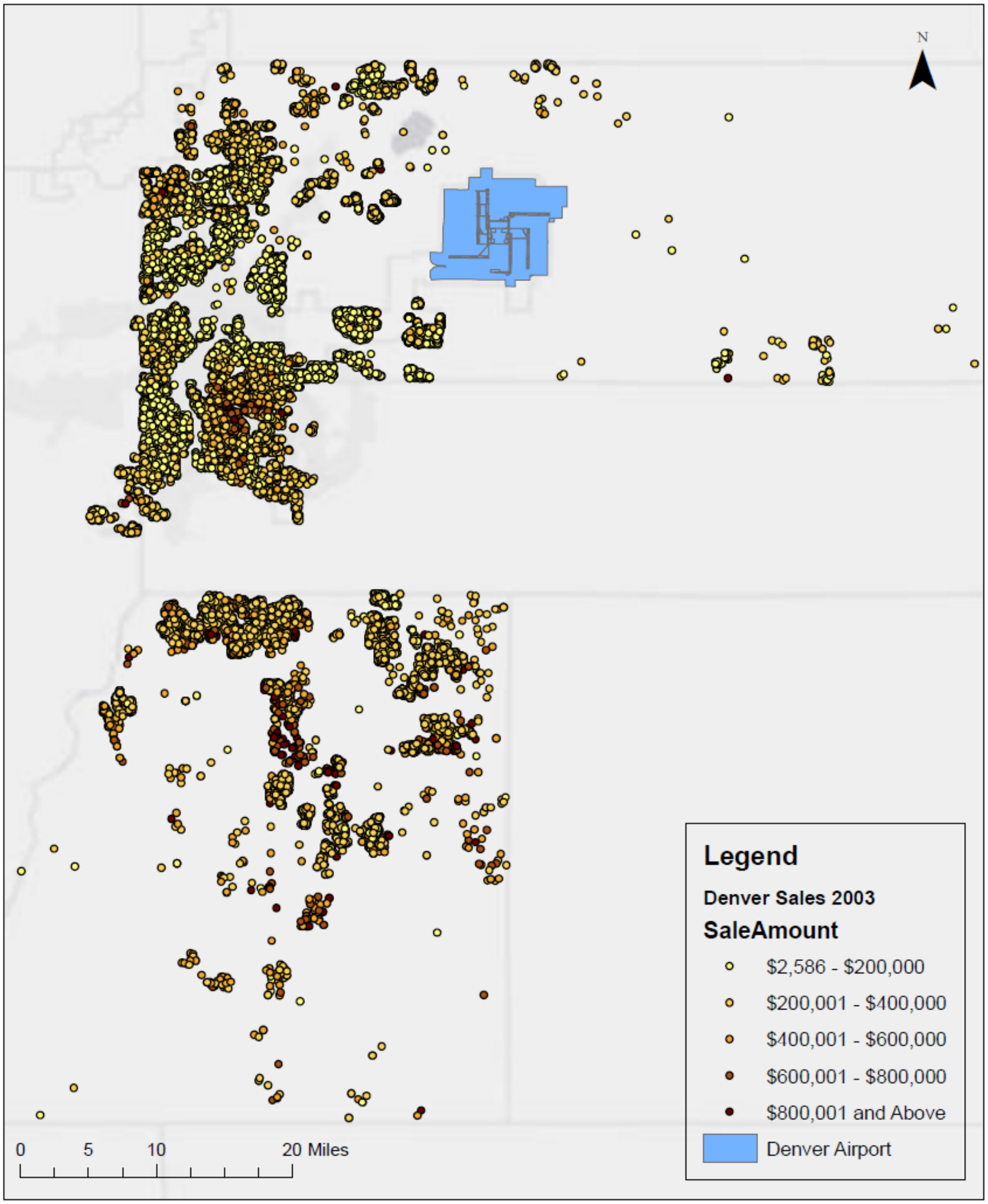


Figure 2b—Single Family Home Sales in 2010 for Denver

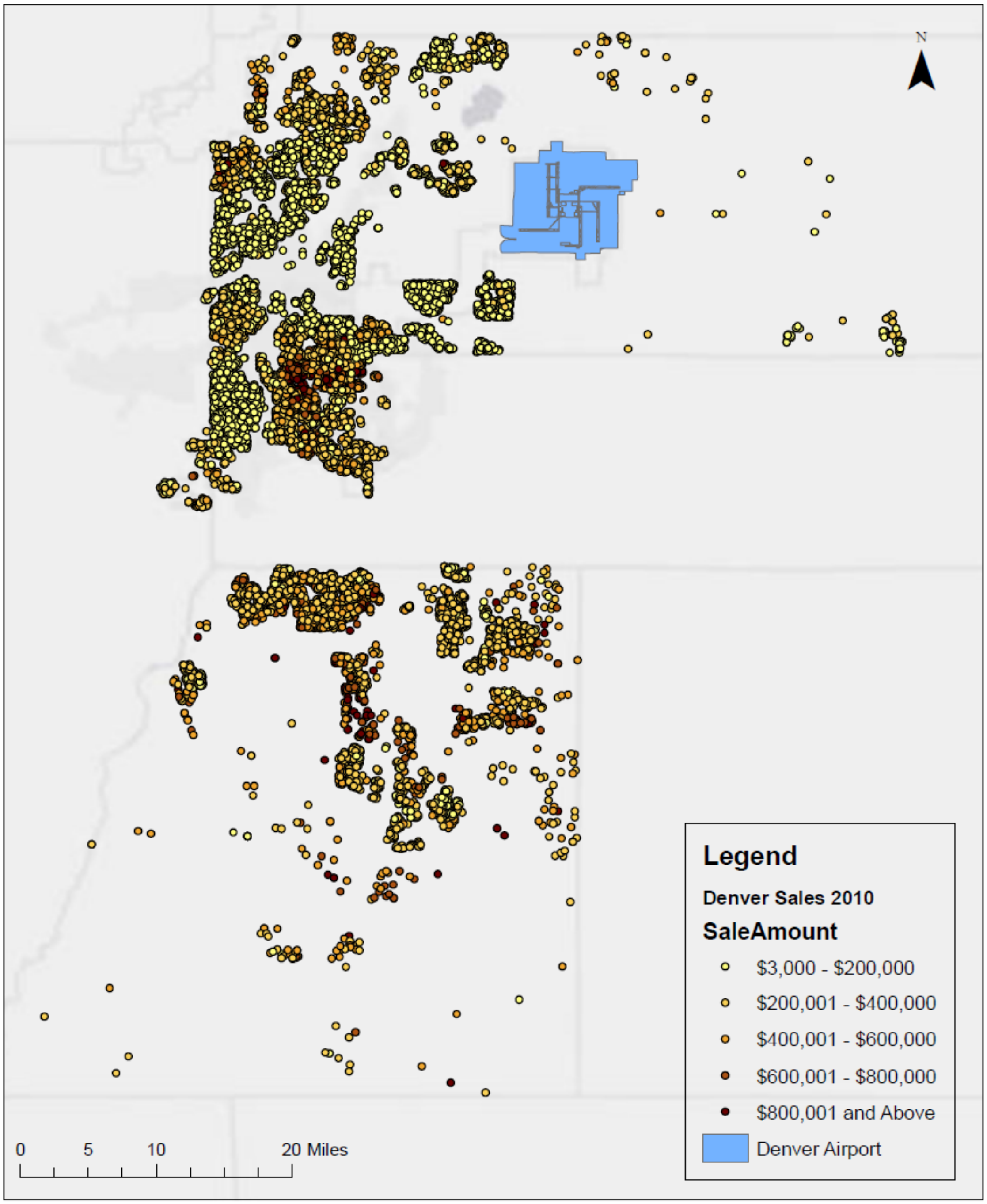
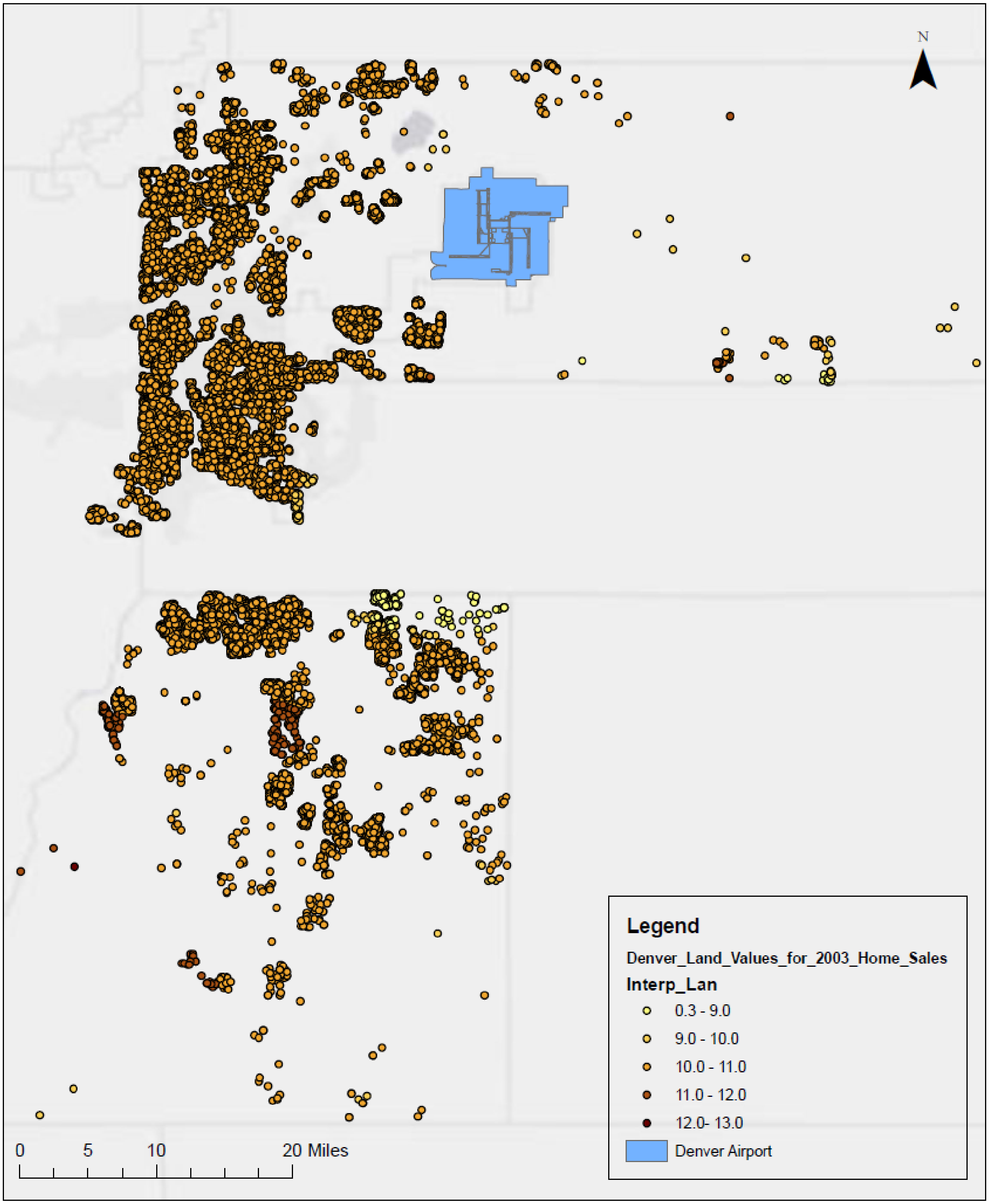
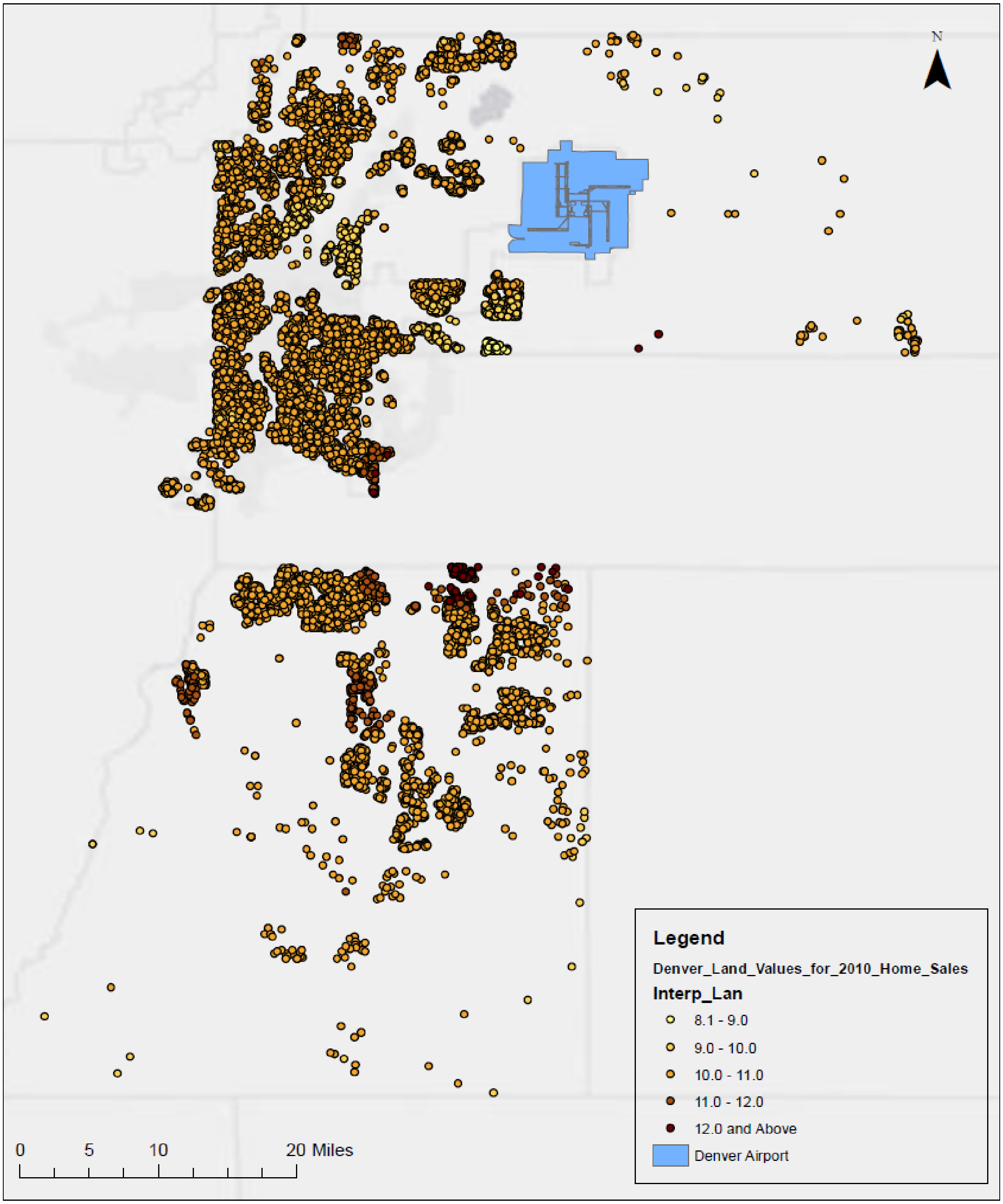


Figure 3a—2003 Land Values for Homes Sold Between 2003 and 2010, Denver



(Note: Land Values are expressed in Natural Logs)

Figure 3b — 2010 Land Values for Homes Sold Between 2003 and 2010, Denver



(Note: Land Values are expressed in Natural Logs)

Table 1a: Descriptive Statistics, Denver Single Family Home Sales, 2003–2010

Variable	Mean	Std. Dev.	Variance	Minimum	Maximum	Valid
Sale Price (Log)	12.3845	0.5543	0.3072	6.9078	15.4249	178,731
Yr2003	0.1403	0.3473	0.1206	0	1	178,731
Yr2004	0.1542	0.3612	0.1305	0	1	178,731
Yr2005	0.1563	0.3632	0.1319	0	1	178,731
Yr2006	0.1419	0.3489	0.1217	0	1	178,731
Yr2007	0.1218	0.327	0.1069	0	1	178,731
Yr2008	0.1082	0.3106	0.0965	0	1	178,731
Yr2009	0.0936	0.2913	0.0848	0	1	178,731
Yr2010	0.0837	0.2769	0.0767	0	1	178,731
No of Bedrooms	3.0209	0.7878	0.6206	1	13	178,731
No of Full Baths	2.2319	0.8794	0.7733	1	12	178,731
No of Half Baths	0.1823	0.3953	0.1563	0	4	178,731
No of Fireplaces	0.6387	0.7121	0.5071	0	9	178,731
Garage Dummy	0.883	0.3215	0.1033	0	1	178,731
Basement Dummy	0.7771	0.4162	0.1732	0	1	178,731
Stories Dummy	0.4887	0.4999	0.2499	0	1	178,731
Adams County Dummy	0.3193	0.4662	0.2174	0	1	178,731
Denver County Dummy	0.3962	0.4891	0.2392	0	1	178,731
Douglas County Dummy	0.2845	0.4512	0.2036	0	1	178,731
Longitude	-104.9153	0.1033	0.0107	-105.233	-103.765	178,731
Latitude	39.7089	0.1678	0.0281	39.1305	40.242	178,731
Longitude Squared	11007.2217	21.6625	469.2655	10767.11	11074.07	178,731
Latitude Squared	1576.8229	13.3123	177.2173	1531.199	1619.4203	178,731
Lat*Lon	-4166.0685	18.4366	339.9078	-4198.466	-4098.49	178,731
Age	37.2061	32.0828	1029.309	2	145	178,731
Age Squared	2413.5977	3523.6018	12415769.35	4.00002	1025	178,731
Land Square Feet (Log)	8.9075	0.6294	0.3962	6.2146	17.204	178,731

Table 1b: Airport Infrastructure Capital Stocks, Denver International Airport, 2003–2010 (millions of dollars)

	2003	2004	2005	2006	2007	2008	2009	2010
Airfield	759.3	735.2	710.6	695.0	678.8	664.0	675.6	670.2
Terminal	592.1	581.4	570.7	591.8	596.6	601.3	590.9	589.1
Parking	88.9	88.4	87.3	96.5	131.2	136.0	139.6	138.9
Road, Rail & Transit	104.4	107.1	111.9	112.3	110.4	113.0	111.7	114.3
Other	385.2	379.1	367.8	358.9	348.3	350.6	345.1	349.6
Total	1929.8	1891.3	1848.4	1854.4	1865.3	1865.0	1863.0	1862.1

Note: capital stock estimates are in constant (2003) millions of dollars, net of depreciation.

Table 1c: Airport Infrastructure Capital Stocks, Atlanta International Airport, 2003–2010 (millions of dollars)

	2003	2004	2005	2006	2007	2008	2009	2010
Airfield	4731.9	4746.5	4674.2	4529.5	4493.4	4330.3	4181.3	4014.0
Terminal	1152.6	1225.7	1237.9	1331.6	1401.6	1394.8	1530.9	1470.1
Parking	43.5	43.1	42.0	44.5	49.1	98.2	96.5	94.1
Road, Rail & Transit	518.1	506.4	506.4	494.9	485.1	561.7	551.1	538.6
Other	1162.9	1135.5	1172.3	1149.4	1146.4	1225.9	1320.7	1588.1
Total	7608.9	7657.1	7632.8	7549.9	7575.6	7611.0	7680.5	7704.9

Note: capital stock estimates are in constant (2003) millions of dollars, net of depreciation.

Table 2—Hedonic Regressions, Denver SFR Home Sales, 2003–2010

Valid cases:	178731	Dependent variable:	Sales Price (Log)
Missing cases:	0	Deletion method:	None
Total SS:	54912.358	Degrees of freedom:	178706
R-squared:	0.598	Rbar-squared:	0.598
Residual SS:	22049.994	Std error of est:	0.351
F(24,178706):	11097.323	Probability of F:	0

Variable	**Coefficient Estimate**	**Std. Error**	**T-Value**	**P-Value**	**Std. Estimate**	**Corr. With Dep Var**
Constant	202.410959	201.0866	1.006586	0.314	---	---
Yr2003	0.068227	0.003635	18.76699	0.000	0.042754	0.012503
Yr2004	0.095813	0.003571	26.8308	0.000	0.062434	0.042892
Yr2005	0.131626	0.003566	36.90899	0.000	0.086239	0.087176
Yr2006	0.129537	0.003629	35.69353	0.000	0.081543	0.079884
Yr2007	0.077005	0.003735	20.61473	0.000	0.045432	0.029024
Yr2008	-0.097482	0.003829	-25.4592	0.000	-0.05462	-0.14588
Yr2009	-0.05641	0.003955	-14.264	0.000	-0.029642	-0.105342
No of Bedrooms	0.012787	0.001343	9.523286	0.000	0.018173	0.313232
No of Full Baths	0.179021	0.001596	112.174	0.000	0.284008	0.580936
No of Half Baths	0.217465	0.00276	78.79305	0.000	0.155101	0.16935
No of Fireplaces	0.200215	0.001473	135.9471	0.000	0.257226	0.546408
Garage Dummy	0.17984	0.002881	62.42511	0.000	0.104302	0.333623
Basement Dummy	0.185322	0.002255	82.17876	0.000	0.139156	0.407872
Stories Dummy	0.004506	0.002503	1.800044	0.072	0.004063	0.374439
Adams County Dummy	-0.020423	0.006856	-2.97888	0.003	-0.017178	-0.252917
Denver County Dummy	0.163774	0.005198	31.50988	0.000	0.144513	-0.094964
Longitude	-14.872111	2.754598	-5.39901	0.000	-2.771709	0.075924
Latitude	-50.073939	5.904851	-8.48014	0.000	-15.156397	-0.330605
Longitude Squared	-0.289046	0.014829	-19.4915	0.000	-11.29638	-0.076057
Latitude Squared	-0.912854	0.039403	-23.1669	0.000	-21.923912	-0.330286
Lat*Lon	-1.165766	0.0492	-23.6944	0.000	-38.775343	0.332441
Age	-0.012165	0.00013	-93.7146	0.000	-0.704107	-0.256053
Age Squared	0.000103	0.000001	101.7823	0.000	0.655769	-0.148225
Land Sq Feet (Log)	0.174666	0.001627	107.3304	0.000	0.198343	0.274045

Table 3—Regression of Log(Land Value/Log Acres) on Airport Infrastructure Investments (Normalized by Distance to the Airport), Including Cross-Sectional and Time Varying Fixed Effects, Denver International Airport

Method: Panel Least Squares
Sample: 2003 2010
Cross-sections included: 178553
Total panel (balanced) observations: 1428424

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-78.83722	30.28399	-2.603264	0.0092
WEIGHTED_AIRFIELD	1.19E-06	3.58E-07	3.342076	0.0008
WEIGHTED_TERMINAL	-2.66E-07	2.66E-07	-1.002248	0.3162
WEIGHTED_PARKING	1.31E-06	1.72E-07	7.587506	0.0000
WEIGHTED_ROAD_RAIL_TRANS	6.09E-06	1.91E-06	3.194300	0.0014
WEIGHTED_OTHER	-7.31E-07	5.01E-07	-1.461118	0.1440

Effects Specification

Cross-section fixed (one dummy for each location)
Period fixed (one dummy for each year)

R-squared	0.946039	Mean dependent var	-2.544193
Adjusted R-squared	0.938330	S.D. dependent var	204.4792
S.E. of regression	50.77933	Akaike info criterion	10.80933
Sum squared resid	3.22E+09	Schwarz criterion	12.33094
Log likelihood	-7541589.	F-statistic	122.7146
Durbin-Watson stat	0.466102	Prob(F-statistic)	0.000000

Note: land values are in real terms, and normalized by the log of acres

Table 4—Regression of First Differences of Log(Land Value/Log Acres) on Airport Infrastructure Investments (Normalized by Distance to the Airport), Denver International Airport

Method: Panel Least Squares
Sample: 2004 2010
Cross-sections included: 178553
Total panel (balanced) observations: 1249871

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.413050	0.060026	-6.881206	0.0000
FIRST_DIFF_AIRFIELD	8.05E-07	1.84E-07	4.372792	0.0000
FIRST_DIFF_TERMINAL	-9.30E-08	1.09E-07	-0.852911	0.3937
FIRST_DIFF_PARKING	6.07E-07	1.41E-07	4.311331	0.0000
FIRST_DIFF_RD_RL_TRN	3.44E-06	1.04E-06	3.295251	0.0010
FIRST_DIFF_OTHER	-9.55E-07	2.08E-07	-4.594995	0.0000

Effects Specification

Period fixed (one dummy for each year)

R-squared	0.000232	Mean dependent var	-0.174310
Adjusted R-squared	0.000223	S.D. dependent var	32.43210
S.E. of regression	32.42848	Akaike info criterion	9.795960
Sum squared resid	1.31E+09	Schwarz criterion	9.796076
Log likelihood	-6121831.	F-statistic	26.38307
Durbin-Watson stat	1.680342	Prob(F-statistic)	0.000000

Note: land values are in real terms, and also normalized by the log of acres

Table 5—Regression of Second Differences of Log(Land Value/Log Acres) on Airport Infrastructure Investments (Normalized by Distance to the Airport), Denver International Airport

Method: Panel Least Squares
Sample: 2005 2010
Cross-sections included: 178553
Total panel (balanced) observations: 1071318

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-1.456716	0.114660	-12.70460	0.0000
SECOND_DIFF_AIRFIELD	1.39E-06	2.52E-07	5.511051	0.0000
SECOND_DIFF_TERMINAL	1.69E-08	2.75E-07	0.061400	0.9510
SECOND_DIFF_PARKING	1.64E-06	1.67E-07	9.814056	0.0000
SECOND_DIFF_RD_RL_TRN	1.03E-05	2.01E-06	5.118815	0.0000
SECOND_DIFF_OTHER	2.31E-07	5.23E-07	0.442338	0.6582

Effects Specification

Period fixed (one dummy for each year)

R-squared	0.000229	Mean dependent var	-0.493552
Adjusted R-squared	0.000220	S.D. dependent var	52.51136
S.E. of regression	52.50560	Akaike info criterion	10.75973
Sum squared resid	2.95E+09	Schwarz criterion	10.75985
Log likelihood	-5763534.	F-statistic	24.52072
Durbin-Watson stat	0.756509	Prob(F-statistic)	0.000000

Note: land values are in real terms, and also normalized by the log of acres

Table 6—Regression of Third Differences of Log(Land Value/Log Acres) on Airport Infrastructure Investments (Normalized by Distance to the Airport), Denver International Airport

Method: Panel Least Squares
Sample (adjusted): 2006 2010
Cross-sections included: 178553
Total panel (balanced) observations: 892765

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-2.254260	0.169981	-13.26180	0.0000
THIRD_DIFF_AIRFIELD	-1.70E-06	9.38E-07	-1.811768	0.0700
THIRD_DIFF_TERMINAL	-1.94E-06	5.67E-07	-3.430999	0.0006
THIRD_DIFF_PARKING	1.39E-06	1.75E-07	7.926691	0.0000
THIRD_DIFF_RD_RL_TRN	-3.35E-06	3.78E-06	-0.886315	0.3754
THIRD_DIFF_OTHER	3.38E-06	1.15E-06	2.941236	0.0033

Effects Specification

Period fixed (one dummy for each year)

R-squared	0.000231	Mean dependent var	-0.751654
Adjusted R-squared	0.000221	S.D. dependent var	71.01746
S.E. of regression	71.00961	Akaike info criterion	11.36352
Sum squared resid	4.50E+09	Schwarz criterion	11.36365
Log likelihood	-5072466.	F-statistic	22.92771
Durbin-Watson stat	0.395905	Prob(F-statistic)	0.000000

Note: land values are in real terms, and also normalized by the log of acres