Longer-Term Housing Market Effects of a Major U.S. Airport Closure

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Abstract: A busy airport's closure has large effects on noise, real estate markets, and neighborhood demographics. Using a unique dataset, we examine the effects of closing Denver's Stapleton Airport on nearby housing markets. We find evidence of immediate anticipatory price effects upon announcement, but no price changes at closing and little evidence of upward trending prices between announcement and closing. However, after the airport closure, more higher-income and fewer Black households moved in, and developers built larger houses on larger lots. These demographic and housing stock changes were also strongly associated with increases in the price of pre-existing housing. Finally, we find that post-closing price increases were largest in areas that were closest to the original airport terminal, a center of new commercial development, and that had greater exposure to new housing construction.

Keywords: Airport noise, housing prices, long-term effects, neighborhood change, dynamic price effects, airport closing, anticipatory effects,

JEL codes: R31, R21, R41, G14

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Introduction

A massive literature examines the effect of local amenities or environment on housing prices.[1] At the same time, most of these studies focus on the direct or short-run effect of the change, while substantial evidence implies that these changes will likely influence the demographic composition of the local neighborhood or community in the long-run. For example, Kahn (2007) and Glaeser, Kahn and Rappaport (2008) document the impact of mass transit expansions on neighborhood income, Banzhaf and Walsh (2008) and Davis (2011) document increasing neighborhood income with air quality, and Banzhaf and McCormick (2006) discuss neighborhood sorting in response to the clean-up of land contamination. In addition, Clapp, Ross and Nanda (2008) show that the demographics of local schools influence housing prices, suggesting that sorting in response to amenity improvements is likely to increase prices further. Identifying these and other longer-run effects is essential for completely assessing the impact of urban amenities on housing prices.

There is very little work examining the long-run or general equilibrium impact of environmental changes on housing prices. Most of the general equilibrium work tends to focus on estimating the correct willingness to pay for environmental amenities given that changes in demographics may lead to changes in resident preferences, as well as

[1] Some examples include studies of property taxes (Ross and Yinger 1998; Lutz 2012; Dhar and Ross 2012), school quality (Black 1999; Bayer, Ferreira and McMillen 2007; Dhar and Ross 2012), crime (Pope 2008; Ihlanfeldt and Mayock 2010), air pollution (Chay and Greenstone 2005; Davis 2011; Currie et al. 2015), land contamination (Kiel and Williams 2007; Greenstone and Gallagher 2008; Taylor, Liu and Phaneuf 2012) and airport noise (briefly surveyed below). See Kahn and Walsh (2015) for a recent discussion of much of this literature.

have independent effects on price (Sieg, Smith, Banzhaf, and Walsh 2004; Walsh 2007; Kuminoff, Smith, and Timmins. 2013).[2] However, economists may reasonably also be interested in the long-run effects of amenities on prices through their general equilibrium effects.[3] On the other hand, several papers find at most modest effects of amenity changes on demographics (Banzhaf and Walsh 2008; Epple and Ferrerya 2008; Ferrerya 2009), attributing the weak effects on income sorting to the fact that only large changes are likely to change the relative ranking of neighborhoods.[4]

We use the closing of Stapleton International Airport in Denver as a case study for examining the medium-run to long-run impact of a large change in location amenity levels on housing markets and prices. The elimination of airport noise is likely to make the location more attractive and also change the demographic composition of residents. Further, the closing frees up developable land that may increase the access of residential housing to other urban amenities. Many studies have examined how airport noise impacts housing prices (Almer, Boes, and Nüesch 2017; Boes and Nüesch 2011; Cohen and Coughlin 2009; McMillen 2004; Mense and Kholodilin 2014; Jud and Winkler 2006), but all of these studies are short-run in focus and to our knowledge only two studies (Thanos et al. 2015 and Breidenbach et al. 2022) have examined the potentially large effects of closing an existing airport.

[2] Also see Coulson and Zabel (2013) who discuss interpretation of hedonic estimates while recognizing that housing prices are often observed when markets are in disequilibrium.
[3] For example, Falck, Fritsch and Heblich (2011) found that the location of baroque opera houses in Europe in the long-run lead to higher human capital, greater knowledge spillovers and faster growth, almost certainly contributing to higher price levels.
[4] For a more complete discussion, see Rosenthal and Ross (2015)

As a baseline, we first use assessor housing transaction files to document the immediate or short-run effects of the announcement and the eventual closing, recognizing that adjustments in prices can begin in anticipation of the future changes in noise levels. While our measure of airport noise is somewhat "noisy" being based on interpolations from historical airport noise decibel maps,[5] we find moderate immediate impacts on housing prices at the time of announcement in 1985. In the year following the announcement, housing prices in the noisiest locations rose by more than 1.5 percentage points per decibel of noise exposure, eliminating over 60% of the 2.5 percentage point lower pre-announcement prices for one decibel higher noise level. We do not find any additional impact on prices at the time of closing in 1995, nor do we observe any systematic trend in prices between 1986 and 1995 as the closing date became closer. Therefore, while we identify moderate impacts of closing associated with properties exposed to higher airport noise levels, all detectable impacts appeared to occur relatively quickly once the closing was announced.

Turning to the focus of our paper, we first examine changes in the composition of new housing construction and in the demographic composition of new residents following the airport closing. We use housing transaction data from 1986 to 2006 on sales of newly constructed housing to relate housing attributes to exposure to noise post-closing in the region around the airport. We find that exposure to higher airport noise levels pre-closing implies substantial increases post-closing in the size of newly constructed housing units. We also use annual Home Mortgage Disclosure Data to

[5] The lowest noise level documented in these maps is 60 db and the vast majority of housing near the airport at the time of the closing announcement was outside of the 60 db contour lines. Therefore, we interpolated decibel levels out to 50 db using 60 db, 65 db, and 70 db contour lines.

examine the income and race of homebuyers using home purchase mortgages between 1990 and 2000 finding that higher pre-closing noise exposure implies higher income and fewer African-American home purchase borrowers post-closing. Both Cutler, Glaeser and Vigdor (1999) and Clapp et al. (2008) find evidence of lower equilibrium housing prices in locations with higher shares of African-Americans.[6]

We then show that these changes in housing construction patterns and in the composition of new home buyers is strongly correlated with changes in housing prices. Specifically, we condition on a sample of housing that was constructed at least three years prior to the closing of the airport to eliminate changes in unobserved housing quality following the closing, and regress housing transaction price on the census tract level averages of square feet of living area of newly built homes and income of home purchase buyers from 1996-2006. Both changes in the size of new construction and in the income of new home buyers are strongly associated with increases in housing prices over time. However, when we investigate the trajectory of housing prices after the airport closing and the relationship of this trajectory with previous exposure to noise, we do not find any relationship between pre-closing noise levels and housing price appreciation.

The lack of evidence of price effects of these longer run changes could arise because buyers were able to anticipate the changes along with the direct change in noise level, or alternatively because these longer run changes might operate over a larger area than the more narrow effect of airport noise. To further investigate this issue,

[6] See Clapp and Ross (2004) for alternative evidence that marginal buyers across housing submarkets eliminate most of the effects of demographic preferences on housing prices. Also see Rosenthal and Ross (2015) for a broader discussion of race, gentrification, and housing markets.

we conduct a longer run analysis through 2016 comparing transaction prices of housing that was built prior to the airport closing to three variables intended to capture specific changes that arose in response to the closing. Specifically, we regress housing prices on the interaction of years since closing with distance to the original airport terminal, since the terminal acted as a center of the growing commercial development, and two time-varying variables based on date of transaction: distance to the closest open park among parks created following the airport closing, and the share of total nearby housing that had been constructed post-closing. Both proximity to the airport terminal, and by implication to commercial development, and increased exposure to newly built housing are associated with increasing housing prices.

These findings provide an important lesson for any studies attempting to assess the long-run effects of amenity changes. The demographic and investment changes resulting from an initial shock to amenity levels are likely to be much more spatially diffuse than the original shock. As a result, these long-run changes may not correlate with the detailed spatial pattern of the initial amenity shock, which is often a key source of variation that is exploited to obtain causality in quasi-experimental analyses of amenities and housing prices.

Background: Stapleton International Airport in Denver[7]

Originally a municipal airport that opened in 1929, Stapleton grew from essentially a 600-acre mail transportation facility to a 1435-acre commercial airport by 1945, and it was the primary commercial airport serving the metropolitan Denver area. Stapleton

[7] Most details in this section of the paper come from the Colorado Encyclopedia, https://coloradoencyclopedia.org/article/stapleton-international-airport (accessed on 10/8/19).

was located near downtown Denver and had 4 runways. In the late 1950s with the advent of jet travel, there was a need for a longer jet-engine runway, and this runway was completed in 1962. Future growth of the airport, however, was limited by its location immediately south of the Rocky Mountain Arsenal and near downtown Denver where airport noise was becoming an increasingly significant issue. By 1985, plans were announced to acquire land for a new airport (Denver International Airport) that was roughly twenty minutes from Stapleton. The new airport opened in February 1995, and simultaneously Stapleton ceased operations. Subsequently, the 7.5 square miles, which is approximately fifteen minutes from downtown Denver, has been in various stages of redevelopment that is continuing to this day.

The resulting urban, in-fill redevelopment was, at one time, the largest ever in the United States.[8] An over-arching goal was to create a pedestrian-friendly, mixed-use environment accessed via short walks and bike rides. Housing, both rental and owner-occupied, would be in close proximity to restaurants, stores, schools, and recreation. Ideally, the new neighborhoods would combine the best things about existing neighborhoods in Denver with new ideas and technology, such as water-wise landscaping and energy efficient building standards. The first resident moved into the newly developed residential area immediately southwest of the original airport terminal in 2002; today, there are more than 32,000 residents living in roughly 14,000 homes, 9000 single-family houses and 5000 rental units. During the period following the closing, many new parks and recreation areas were created within and around the original

[8] For additional details, see https://www.denver80238.com.

airport footprint, and substantial new in-fill owner-occupied housing construction took place in pre-existing neighborhoods around the airport.

Given the uniqueness of this airport closure and redevelopment, Stapleton is an ideal setting to examine how an airport closing can impact single-family residential real estate markets. While there is a significant literature on airport noise and house prices, the closure of Stapleton provides us with a relatively unique setting to study the long-run impacts of a major land-use change that increases local amenity levels and opened up substantial land for re-development.

Data

As indicated earlier, our data come from several sources. First, the Denver assessor provided population data on housing sales 1987 onward. We also scraped sale price and property address data from 1984 and 1986 from the online Denver land records. After geocoding these data, we matched the property-level data with property characteristics data from the Denver assessor's database. We also matched each property address to the corresponding census tract, and then merged in the average income and percent Black population for each tract in each year using individual-level Home Mortgage Disclosure Act Data (HMDA) that we averaged for each tract dropping mortgages not designated for owner-occupancy to assure that purchaser and the new resident are the same. While the tract definitions used for HMDA reporting changes from 1990 to 2000 in 2004, we match housing data at the transaction level so that HMDA data in a given year is based on tract definitions for that particular HMDA year.

The noise data was obtained for 1985 and 1995 from various Federal Aviation Administration reports, which we geocoded using ArcGIS software. We create a rough proxy for noise levels interpolated as the noise levels between the contours, and since the smallest noise contour was 60 dB, we extrapolate to 50 dB using the slope of the noise relationship between 65 and 60 dB using the shortest distance between those two noise contours to estimate noise along a ray extending out from the 60 dB contour. This led to a continuum of noise levels throughout the properties in our dataset, which was especially important if we are going to exploit variation within census tracts where discrete changes in assigned noise level from crossing a contour line would be very misleading. All samples for regressions involving noise exposure are based on housing units that are predicted to have been exposed to 50 dB or higher levels of noise due to concerns that contour interpolation would become unreliable at more than 10 dB from our outermost noise contour line. While our estimated measures of noise exposure may not exactly capture decibel levels, it should provide a relatively monotonic proxy for noise levels.

We present several tables of descriptive statistics for our data. The Appendix shows the descriptive statistics for the variables used in the 1984-86 and 1994-96 samples for assessing effects of the closure announcement and the actual airport closure dropping the announcement and closure years of 1985 and 1995. We restricted our attention to properties that were built in 1984 or earlier because we wanted to retain consistency in the construction range and housing unit composition across both samples. We were able to obtain information on 838 arms-length single family residential sales in our 1984/86 sample and the assessor’s data contained 2,812 arms-length sales in these same neighborhoods in our 1994/96 sample. The average house that sold in 1984 and 1986 had a price of approximately $83,000, while the typical house sold in 1994 and 1996 had a price of approximately $106,000. In both samples, the average house was exposed to approximately 55dB of noise.

Table A-2 in the Appendix contains descriptive statistics samples of housing transactions between announcement and closing and post-closing. The top panel is for sales of properties built between the years 1985-95, and the bottom panel is for sales of properties built between the years 1996-2016. In the top panel of Table A-2, the average year of construction was 1989, while in the bottom panel the typical house was built in 2002. The average house built post-1995 had a larger number of bedrooms, more bathrooms, and greater living area (square footage). For houses sold between 1985-95, the typical house was exposed to 56.6 dB of noise, while for sales between 1996-2016 the typical house was in an area that used to be exposed to over 59 dB of noise based on the historical contour lines, but presumably was exposed to little or no noise at the time of sale because the airport had closed in 1995. Anecdotally, it appears that larger houses were being built in neighborhoods that were being redeveloped after the closure of the old airport.

In the Appendix, Table A-3 shows the descriptive statistics for the average income and percent Black of home purchase mortgage borrowers. These data come from individual HMDA data that we have obtained at the census tract level merged with our housing transaction data at the census tract level. The average income for the tracts where properties sold was approximately $79,000, and the average tract where properties sold had roughly 14% Black population. In this sample, the average noise exposure pre-1995 was again approximately 55 dB, but post-1995 the average exposure to pre-closing noise levels was substantially higher.

Maps of the pre-closing housing transactions in Denver County that were exposed to airport noise estimated to be 50 decibels or higher are presented in Figures 1a and 1b. In these maps, one can see the locations of the 1984 and 1986 sales in the top panel of Figure 1, as well as the associated extrapolated/interpolated noise level for each property. The bottom panel of Figure 1 shows the sales in 1994 and 1996 as well as the noise level exposure based on the extrapolated/interpolated 1995 noise data. The solid line represents the boundary of Denver Country. While the noisy boundaries are continuous over space, the area available for pre-existing housing was limited by both airport boundaries and land use zoning. In viewing these maps, we identify 3 clusters of pre-existing residential housing (loosely referred to as “broader neighborhood groups”).

[Figure 1 Here]

In a second figure, we illustrate the construction of new housing for the period from when the closing was announced to actual closure and then for five-year periods after the closing through 2010. The location of the original airport terminal is indicated by the airplane image, and the pre-closure noise contour lines are shown by dashed or solid lines. The black dots in each subfigure show the housing built during the period covered by that subfigure, and the gray dots indicate housing built prior to the start of that period. So, for example in the upper left-hand subfigure, the black dots show housing that was built between the announcement of the closing and the actual closure, and the gray dots show housing built before the announcement. The concentrated area of black dots just south of the airport terminal in the 2000-05 and 2006-10 subfigures represent the new owner-occupied housing construction that was part of the airport property redevelopment plan.

[Figure 2 Here]

Results

Analysis of Announcement and Closure Effects

To examine the immediate effect of the announcement and the actual closing on housing prices, we conduct a differences-in-differences analysis within a very narrow time window of these events. Specifically, we select data one year before and one year after the announcement and one year before and after the closing of Stapleton, and we estimate for each of these events separate hedonic housing price models. Specifically, we specify the difference-in-differences model interacting the level of noise experienced by different houses near Stapleton with each event to see if either the announcement or the closing leads to a smaller (absolute) effect of noise on housing prices (y_{itl}). This approach leads to the following model (assuming a semi-logarithmic functional form):

$$Log(y_{itlc}) = \beta_0 X_{it} + \beta_1 N_l + \beta_2 E_t + \beta_3 N_l E_t + \delta_c + \varepsilon_{itlc} \qquad (1)$$

where X_{it} is a standard set of hedonic housing attributes, N_l is the noise associated with a given location l, E_t is a dummy variable that is one if the transaction occurs in the year following the event and zero if the transaction occurs in the year before the event, β_3 captures the effect of the event on the relationship between airport noise and housing prices, and δ_c is a set of geographic fixed effects, either broader neighborhood groups or census tracts within these neighborhoods. Standard errors are clustered at the census tract level for these models and all models that follow.

The difference-in-differences results are presented in Table 1. The first two columns, using data for 1984 and 1986 sales, are the results for the 1985 announcement with either tract (column 1) or broader neighborhood fixed effects (column 2). The coefficient magnitudes on both noise and the interaction of noise with the announcement are quite stable across the two specifications. They are consistent with an approximate 5 dB increase in noise level (based on our interpolations) implying cross-sectionally or within census tract a 12 percent decrease in housing prices. However, after the announcement, most of that negative effect is eliminated because the estimate on the interaction with the announcement implies an offsetting 8 percent increase in prices for a 5 dB increase in noise. The interaction coefficient is somewhat noisy, but is significant at the 10 percent level in our preferred specification with census tract fixed effects. On the other hand, looking at columns 3 and 4, the closing of the airport had virtually no impact on the influence of noise on housing prices in either specification.

[Table 1 Here]

This lack of an immediate change in prices upon closing is not completely surprising since the closing could have been fully anticipated by homeowners and homebuyers. In fact, looking at the level coefficient on noise, i.e., the effect of noise levels immediately prior to closing, those estimates are statistically insignificant and for the preferred tract fixed effects model are very close to zero. To test for gradual changes in prices, we select a sample starting in 1984 as a base year and then from

1986 to 1994 just prior to closing.[9] We then replace the event variable in equation (1) with either a linear year trend or a vector of dummy variables for each year that take the value of one from that year forward where 1984 is the omitted year. As a result, estimates on these year variables can be interpreted as the year-to-year change in the price index and the total change is captured by adding up all of the individual point estimates.

Table 2 presents these results with the first panel presenting the estimates on a linear trend interacted with noise and the second panel presenting the estimates of individual year dummy variables interacted with noise. The coefficients on the interaction of noise with a linear trend are very near zero, so that over the 10-year period the estimates imply less than a one-percent decline in housing prices. Looking at panel 2 of Table 2, while some individual year to year changes are sizable and significant (perhaps due to an event related to airport closure that we do not observe), the sum of the individual point estimates in panel 2 falls between 0.5 and 1.0 percent increase in housing prices over the 10 year period. Therefore, we find no consistent evidence of any gradual increase in prices between the announcement and the actual closure. Accordingly, we conclude that the direct effects of closure on prices through reducing airport noise arose relatively quickly after the announcement of the planned closure.

[Table 2 Here]

[9] Due to the arduous process of hand collecting data from the mid-1980's, we focused our resources on gathering property sales records for 1984 and 1986 and therefore do not have any transactions for the year 1985.

Finally, we consider several checks for the validity of our empirical approach above. First, we perform a traditional balancing test by re-estimating equation (2), using sales data from 1980 and 1984[10] (i.e., before the announcement) where we regress the housing attributes of these pre-1985 sales on the noise level. Next, we consider a simple falsification test where we assume there is a "fake" announcement in 1982, and we re-estimate equation (1) using data from 1980 and 1984 sales. Finally, we conduct an alternative falsification test where we identify transactions that are very similar to the transactions that occurred near the airport.[11] We then run the same regressions as were run for Table 1, but replacing each transaction in those samples from 1984, 1986, 1994 and 1996 with the property from outside the airport region with the closest match on likelihood of being exposed to high noise levels. These results are shown in Table A-4. We pass all balancing tests, and while some falsification estimates are statistically significant none can explain our findings on housing price.

Effects on Housing Construction and Home Buyer Demographics

Next, we conduct tests that might indicate evidence of indirect effects on housing prices in the area during this period. First, we test the hypothesis that "better" houses were built in areas originally exposed to high levels of airport noise after the old airport

[10] Our choice of 1980 and 1984 for the balancing test and the subsequent falsification test was guided by the data that we had available. Previously we had manually collected data for 1980 sales from the Denver assessor online records, and we had already collected 1984 property sales from the same source. Given the extremely labor- intensive process of obtaining the data for other years, we determined the most feasible dataset for the model validations would focus on 1980 and 1984, with a 1982 date for the "fake" announcement.

[11] Specifically, we regress a dummy for high noise levels, over 50 dB, on the hedonic attributes: log of bedrooms, log of bathrooms, log of square feet of living space, log of square feet of lot size, and age of property; separately by transaction year for our samples of transactions near the airport. We use this propensity score to identify transactions within Denver that are of very similar housing units, but not exposed to the noise.

closed and the land began to be redeveloped. Specifically, we estimate separate models before and after the closing and compare the estimates on noise β_{1D} across the two time periods D.

$$X_{itl} = \beta_0 + \beta_{1D} N_l + \delta_{cD} + \gamma_{tD} + \varepsilon_{itl} \quad (2)$$

where δ_{cD} is the vector of census tract fixed effects for each period and γ_{tD} is the vector of time fixed effects for each period. A comparison of the estimates on β_{1D} will indicate whether the type of housing units being built in areas most affected by airport noise changes after the closing. These models will be estimated only for the sale of newly built housing units in the periods leading up to and following the closing of the airport.

Table 3 presents these estimates for four key hedonic attributes: number of bedrooms, number of bathrooms, living square feet and land or lot size square feet. The first column for each attribute presents the relationship with noise for a sample of sales of new housing built during the decade between the announcement and the closing of the airport, and the second column presents the estimate on noise for the sample of new housing built and sold for the years following the closing. For all attributes, the first column for the pre-closing sample shows strong negative effects of noise on the number of bedrooms, bathrooms, interior square feet and square feet of lot size. For example, an interpolated 5 dB change in noise implied a decline of more than ½ a bathroom and of approximately 700 square feet of interior space. However, in the second column after closing, the estimated effects of airport noise on the attributes of newly built housing are virtually zero. Post-closing, builders no longer respond to the old noise contours in any observable way. While we do not observe measures of housing quality, new construction in this area is associated with larger houses on larger lots, which is consistent with more expensive, higher quality houses.

[Table 3 Here]

We next consider how the demographics of homebuyers changed after the closing of Stapleton. Since our HMDA data only begins in 1990, we consider home purchases and mortgage borrowers between 1990 and 2000 so that our data is centered around the closing date. Our sample is still at the individual housing transaction level, and census tract fixed effects are based on a common 2000 Census tract definition. However, our measure of demographic attributes of buyers associated with each sale Z_{ct} suffers from substantial measurement error because location is only identified in the HMDA data down to the census tract and the tract definitions used in HMDA change in 2004. While this does not lead to bias since the measurement error is on the left-hand side, it does reduce precision and so we pursue an interactive model estimating:

$$Z_{ict} = \beta_0 + \beta_1 N_l + \beta_2 E_t + \beta_3 N_l E_t + \delta_c + \gamma_t + \varepsilon_{itlc} \quad (3)$$

where again β_3 identifies the effect of the closing on the relationship between the demographics of buyers and airport noise. These models will be estimated using a sample of sales, but the dependent variable in each census tract and year is a composite of attributes of all home purchase mortgage borrowers in that tract-year cell.

As with the housing characteristics, properties that sold in 1995 or later exhibit a positive, statistically significant impact on average income and negative impact on share Black of homebuyers in locations with higher noise. However, the magnitudes of the estimated effects as shown in Table 4 are modest. Looking at the interaction coefficients, a 5 dB decrease after 1995 implies annual incomes of homebuyers that are $350 higher and a population of homebuyers that is 0.3 percentage points less likely to be Black, which represents a 2 percent decrease in the mean share Black among homebuyers of 14 percent.[12]

[Table 4 Here]

Longer-run Housing Price Patterns

First, we estimate a model of housing price changes between the year after the closing (i.e., 1996) until 2006, using sales of pre-existing housing to test whether housing appreciates more in areas that were previously exposed to higher levels of airport noise. As in Table 2, we replace the event variable in equation (1) with a linear year trend and an interaction of that trend with our airport noise variable. Table 5 presents these results. The coefficients on the interaction of noise with a linear trend are again very near zero, so that over the 10-year period the estimates imply only a 0.3 percent decrease in housing prices. Surprisingly, we do not find rising housing prices during this period even though higher income households are moving into the locations that had been exposed to more noise and nice houses are being built there. One possibility is that buyers can anticipate the longer run effects of the reduction in noise level in addition to the direct benefits of declining noise. However, another possible

[12] In Table 4, Year_1995 is an indicator variable that equals 1 when a sale occurred between 1995 and 2000 (i.e., after the closure of the airport), and 0 if the sale occurred between 1990 and 1994 (before the closure). In contrast, Year_1995 in Table 1 refers only to sales that occurred in 1996 (one year after the 1995 closure).

explanation is that the benefits of improved neighborhood quality are operating at a broader scope than the quite narrow spatial variation in pre-airport closing noise exposure. It is notable that there is a significant positive trend in housing prices overall based on the coefficient estimate for the trend, and this price growth might be driven by the broader redevelopment of the airport property.

[Table 5 Here]

To examine this issue, we further explore the evolution of housing prices in the area surrounding the airport following the airport closure. We begin by examining the relationship between changes in housing quality through new building and changes in demographics through new homebuyers on the dynamic process of housing price adjustment. Specifically, we estimate the standard log-linear housing price hedonic model including controls for 3-year moving averages of the changes in the attributes of new housing being built and the income of new homebuyers in these locations.[13] For this analysis, we restrict the sample to sold housing units that were built at least three years before the airport closing so that we are not picking up changes in unobservable housing attributes that arose in the immediate run up to and following the closing.

$$Log(y_{itlc}) = \beta_0 X_{it} + \beta_1 N_l + \beta_2 \bar{X}_{ct-3} + \beta_3 \bar{Z}_{ct-3} + \delta_c + \gamma_t + \varepsilon_{itlc} \quad (4)$$

where $\bar{X}_{ct-3}$ is the three-year moving average prior to year t of housing attributes of newly built housing in tract c, $\bar{Z}_{ct-3}$ is the three-year moving average prior to year t of

[13] As discussed above, past research documents a relationship between housing prices and racial composition given the dominant role white households play in the market for owner-occupied housing, but housing segregation and racial preferences are beyond the scope of this paper, so we focus on borrower income which is thought to have a more direct connection to neighborhood amenity levels.

borrower demographics for all home purchase mortgages in tract c and in this model γ_t represents month by year fixed effects.

Table 6 Panel 1 presents these results. The first column presents results on the effects of increases in the living space of newly built housing, the second column present results on the effects of increases in the income of new homebuyers, and the third column includes both variables. We find positive effects of both variables. Both the building of larger houses and the fact that higher income households are moving into the locations that were previously noisy imply higher housing prices over time.

The regression is log-log so that the coefficients on the log of the three-year lagged moving averages can be interpreted as elasticities. The elasticities are quite sizable in our assessment. Focusing on the “Both” column, a 10 percent increase in the average income of recent home buyers is associated with a 4.4 percent increase in housing prices. This estimate is quite large given that changes in neighborhood income are limited by the presence of longer-term residents. Meanwhile, a 10 percent increase in the square footages of newly built homes is associated with a 1.6 percent increase in housing prices. While in many situations an elasticity of 0.16 would be viewed as small, the right-hand side variable here only captures changes in the size of new housing being built, and so changes in the overall housing composition is small because the bulk of housing stock was built before the airport closed. Panels 2 and 3 present results using the current year value or a five-year moving average, respectively, and results are similar. These results are suggestive that changes in demographics and housing quality may have contributed to increasing housing prices, even though we found no direct relationship between price appreciation and exposure to pre-closure noise levels.

[Table 6 Here]

Finally, we attempt to tie increases in housing prices more directly to specific changes that occurred following the closure of the airport. We create three new variables that we include in a model based on the housing price trend model discussed above and shown in Table 5: 1. A measure of distance to the airport terminal (the center of a substantial amount of commercial development) and its interaction with the post-closing time trend, 2. A time-varying variable measuring distance to the closest open park that was created following the airport closure, but prior to the transaction, and 3. A time-varying variable measuring the share of total housing stock within one mile at the time of the transaction that was constructed post airport closing. All models are estimated using a sample of transactions from 1996-2016 of housing constructed prior to the airport closing.

These results are shown in Table 7. Our baseline model includes distance to the terminal and the interaction with the time trend. Then, the column 1 model includes the time varying control for distance to nearest park, and the column 2 model includes the share of surrounding housing that was built since the airport closing. The interaction of distance is negative and strongly significant suggesting that housing price appreciation was much faster in areas closer to the planned development around the original airport terminal. While somewhat noisier, the estimate on share of housing that was constructed post-closing is also positive implying that pre-existing housing appreciated in value more rapidly in locations where substantial in-fill housing construction has taken place following the closing of the airport. Therefore, while the pre-closing noise level is not associated with rising housing prices over time, we observe rising prices for houses that are exposed to specific changes that are attributable to the airport closing. We do not find any evidence that prices were influenced by proximity to new parks.

[Table 7 Here]

Conclusion

This paper examines medium-run and long-run implications of the closing of Stapleton airport in Denver. After demonstrating that the airport closing did represent an amenity improvement based on higher housing prices after announcement, we examine changes in the composition of the newly built housing and new home buyers in areas near the airport that traditionally had experienced more noise. Focusing on new construction, we find that bigger and “nicer” houses were built and sold after the closure, in areas that were formerly relatively noisy before the closure. We also find that after the closure the average incomes of homebuyers rose and the likelihood that a homeowner was Black fell in the areas that were formerly exposed to higher levels of airport noise.

We then turn to housing price changes after the closing of the airport. We do not find any impacts on housing prices in the narrowly defined geographies associated with variation in pre-closure airport noise exposure. Therefore, any longer-run impacts of the closure are not tied specifically to the locations that saw a large reduction in noise. Next, we examine whether the changing composition of new homebuyers and newly built housing units has dynamic effects on housing prices following the closing of the airport. We find that housing prices are higher in neighborhoods near the airport that experienced either increases in the size of housing being built in terms of square feet and/or increases in the income of homebuyers. Finally, we measure three specific attributes that were affected by the closure: proximity to new commercial development as proxied by distance to the original airport terminal, access to new parks that were created after the airport was closed, and exposure to a larger share of newly constructed housing units post airport closure. Both proximity to the original terminal and exposure to post-closing constructed housing are associated with higher prices.

While many studies have examined how airport noise impacts house prices, our study provides unique evidence on the long-run impacts on housing prices through migration of new home buyers, decisions of builders concerning the size and quality of housing units and commercial development. The availability of new land for in-fill development can contribute substantially to the desirability of a location, and household sorting over these amenities can change the composition of neighborhoods reinforcing the price effects. Past research has tended not to consider these longer run, general equilibrium impacts of environmental amenities and disamenities, both overall and in the context of airport noise. Further, based on our findings, traditional quasi-experimental approaches are unlikely to be able to detect these broader, long-run effects because the changes that follow any initial shock to amenities are likely to be much more spatially diffuse than the initial shock and so have similar influence on both areas immediately impacted by the shock and nearby areas that might traditionally act as controls.

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Table 1: Log Housing Price Hedonic Regression, 1985 Announcement and 1995 Closing

	1985 Announcement		1995 Closing	
	Tract Fixed Effects	Group Fixed Effects	Tract Fixed Effects	Group Fixed Effects
Noise	-0.024**	-0.025**	-0.004	-0.014
	(-2.26)	(-2.62)	(-0.58)	(-1.12)
Noise*Year_1986	0.017*	0.016	-	-
	(1.72)	(1.49)	-	-
Year_1986	-0.873	-0.789	-	-
	(-1.61)	(-1.41)	-	-
Noise*Year_1996	-	-	-0.002	-0.001
	-	-	(-0.46)	(-0.33)
Year_1996	-	-	0.331	0.296
	-	-	(1.67)	(1.16)
Log of Total Bathrooms	0.062*	0.095**	0.028	0.062
	(1.72)	(2.45)	(1.05)	(1.52)
Building Age	-0.000	-0.000	0.004*	0.004*
	(-0.06)	(-0.15)	(1.91)	(1.91)
Log of Bedrooms	0.112	-0.020	0.103**	0.017
	(1.59)	(-0.34)	(2.67)	(0.36)
Log of Living SF	0.334***	0.513***	0.416***	0.692***
	(6.53)	(8.78)	(7.49)	(9.22)
Log of Land SF	0.034	0.057	0.282***	0.292***
	(0.41)	(1.04)	(5.00)	(3.12)
Constant	9.442***	8.266***	5.285***	4.169***
	(12.53)	(12.64)	(6.87)	(3.32)
R-Squared	0.474	0.372	0.721	0.493
Observations	838	838	2,812	2,812

Notes: The first two columns of Table 1 indicate that the treatment effect from the 1985 airport closure announcement is negative and marginally significant, and the last two columns indicate the treatment effect of the actual closure in 1995. Columns 1 and 3 are the tract fixed-effects results and Columns 2 and 4 are the group fixed effects results. Standard errors clustered by tract. *, **, and *** mark significance at the 0.10, 0.05, and 0.01 levels, respectively.

Table 2: Trends in Housing Prices of Pre-existing Housing between 1984 and 1994

Panel 1 - Year Linear Trends

	Group Fixed Effects	Tract Fixed Effects
Trend	0.060	0.045
	(1.11)	(0.79)
Noise*Trend	-0.0008	-0.0006
	(0.86)	(0.58)

Panel 2 - Non-parametric Trends

	Group Fixed Effects	Tract Fixed Effects
Noise*Year 1986 or Later	0.013	0.016
	(1.36)	(1.57)
Noise*Year 1987 or Later	0.005	-0.005
	(0.61)	(-0.89)
Noise*Year 1988 or Later	0.007	0.010
	(0.87)	(1.47)
Noise*Year 1989 or Later	-0.026***	-0.021***
	(-3.70)	(-3.84)
Noise*Year 1990 or Later	0.023**	0.018**
	(2.75)	(2.09)
Noise*Year 1991 or Later	-0.024**	-0.024**
	(-2.11)	(-2.73)
Noise*Year 1992 or Later	0.016*	0.018**
	(1.83)	(2.61)
Noise*Year 1993 or Later	-0.005	-0.004
	(-0.76)	(-0.82)
Noise*Year 1994 or Later	0.001	-0.003
	(0.11)	(-0.66)

Notes: Table 2 examines housing prices for sales between 1984 and 1994. All models control for the noise variable, hedonic controls and year fixed effects. Panel 1 present results based on interacting noise with a linear year trend, and Panel 2 presents results interacting noise with individual year dummy variables. Column 1 reports models using spatial groups, and Column 2 reports results using controls for the census tracts (which are smaller than the spatial groups). T-statistics in parentheses. Standard errors clustered by tract. *, **, and *** mark significance at the 0.10, 0.05, and 0.01 levels, respectively.

Table 3: Regressions of Housing Characteristics from Sales of New Properties

Dependent Variable:	Bedrooms		Total Bathrooms		Living SF		Land SF	
Year Built:	1985-95	Post-1995	1985-95	Post-1995	1985-95	Post-1995	1985-95	Post-1995
Noise	-0.044***	-0.009	-0.140***	-0.001	-120.0***	-19.77	-425.7***	5.922***
	(-99.67)	(-0.59)	(-1,165)	(-0.52)	(-1,203)	(-0.92)	(-1,229)	(4.52)
Constant	5.234***	3.429***	10.17***	3.707***	8,107***	2,921**	26,768***	3,715***
	(160.11)	(4.68)	(1,435)	(31.38)	(1,064)	(2.59)	(1,319)	(27.34)
R-Squared	0.028	0.024	0.088	0.271	0.160	0.149	0.161	0.211
Observations	2,277	6,077	2,277	6,077	2,277	6,077	2,277	6,077

Notes: Table 3 shows OLS regression results of individual house characteristics (Bedrooms, Total Bathrooms, Living SF, and Land SF) on noise using a sample of sales of newly constructed housing for the period leading up to the closure of Stapleton Airport (1985-95) and after the closure (Post-1995). T-statistics in parentheses. All specifications include tract and year fixed effects. Standard errors clustered by tract. *, **, and *** mark significance at the 0.10, 0.05, and 0.01 levels, respectively.

Table 4: Regressions Results for Properties Sold Between 1990 and 2000

Dependent Variable:	Log Avg Income	Log Avg Pct Black
Noise	19.98	-0.011
	(0.44)	(-0.30)
Noise*Year_1995	71.88***	-0.065***
	(5.28)	(-5.02)
Constant	32,086***	11.90***
	(10.59)	(7.10)
R-Squared	0.900	0.958
Observations	14,941	14,941

Notes: Table 4 shows regressions of tract-level log of average income data (column 1) and tract-level log of average percentage Black population (column 2), against noise and noise interacted with a dummy for post airport closing at individual properties in the corresponding tracts for all transactions between 1990 and 2000. T-statistics in parentheses. All specifications include group and year fixed effects. Standard errors clustered by tract. *, **, and *** mark significance at the 0.10, 0.05, and 0.01 levels, respectively.

Table 5: Trends in Housing Prices of Pre-existing Housing between 1995 and 2006

	Group Fixed Effects	Tract Fixed Effects
Trend	0.104***	0.099***
	(2.99)	(2.80)
Noise*Trend	-0.0004	-0.0003
	(0.63)	(0.43)

Notes: Table 5 shows results based on regressing housing sales price for sales between 1995 and 2006 on a yearly time trend and the interaction of that trend and noise. All models include the control for noise and either spatial group (column 1) or census tract (column 2) fixed effects. T-statistics in parentheses. Standard errors clustered by tract. *, **, and *** mark significance at the 0.10, 0.05, and 0.01 levels, respectively.

Table 6: Hedonic Model for Post-1995 Transactions

	Square Feet Living Area	Tract Income	Both
Three Year Sq FT	0.113***	-	0.157***
	(7.22)	-	(10.19)
Three Year Tract Inc	-	0.428***	0.437***
	-	(37.18)	(37.89)
One Year Sq FT	0.061***	-	0.080***
	(4.21)	-	(5.57)
One Year Tract Inc	-	0.346***	0.348***
	-	(34.33)	(34.53)
Five Year Sq FT	0.107***	-	0.127***
	(6.27)	-	(7.52)
Five Year Tract Inc	-	0.439***	0.442***
	-	(35.39)	(35.64)

Notes: Table 6 shows results based on regressing housing sales price for sales post 1995 on three year moving averages of either square feet of living area associated with newly built homes and/or average income of homebuyers. T-statistics in parentheses. All models include tract and year fixed effects. Standard errors clustered by tract. *, **, and *** mark significance at the 0.10, 0.05, and 0.01 levels, respectively.

Table 7: Trends in Housing Prices between 1995 and 2016

	New Housing Density	Distance to New Parks
Log(new housing density)	0.0239*	-
	(2.01)	-
Log(New Parks Distance)	-	0.0720
	-	(1.62)
Trend	0.117***	0.168***
	(6.35)	(4.02)
Log(Stapleton Distance)	0.334**	0.312***
	(2.62)	(2.93)
Log(Stapleton Distance)*Trend	-0.0102***	-0.0143***
	(-4.84)	(-2.89)

Notes: Table 7 column 1 shows results based on regressing log of housing sales price for sales between 1995 and 2016, on log of new housing density, a yearly time trend, the log of distance to Stapleton, and the interaction of the trend and log of distance to Stapleton. The value of the new housing density regressor associated with each sale observation i is calculated as the number of new construction houses built after 1995 but before the date of sale observation i, within 0.5 miles from sale observation i. Table 7 column 2 shows results based on regressing log of housing sales price for sales between 1995 and 2016, on the log of distance to the closest "new" park, a yearly time trend, the log of distance to Stapleton, and the interaction of the trend and log of distance to Stapleton. The locations of "new" parks (the coordinates of their parking lot(s)) are based on City of Denver's acquisition date for several park sites (Central Park, Fredrick Douglass, Westerly, Greenway, and Sand Creek). Park locations and their acquisition dates were obtained from the Denver Open Data website (https://denvergov.org/opendata/dataset/city-and-county-of-denver-parks , accessed 1/2/2022). All models include census tract fixed effects. T-statistics in parentheses. Standard errors clustered by tract. *, **, and *** mark significance at the 0.10, 0.05, and 0.01 levels, respectively.

Figure 1: Random Sample of Denver Single-Family Residential Property Arms-Length Sales and Noise Exposure, 1984 and 1986 (Top Panel) and Population of Arms-Length Sales in 1994 and 1996 (Bottom Panel)

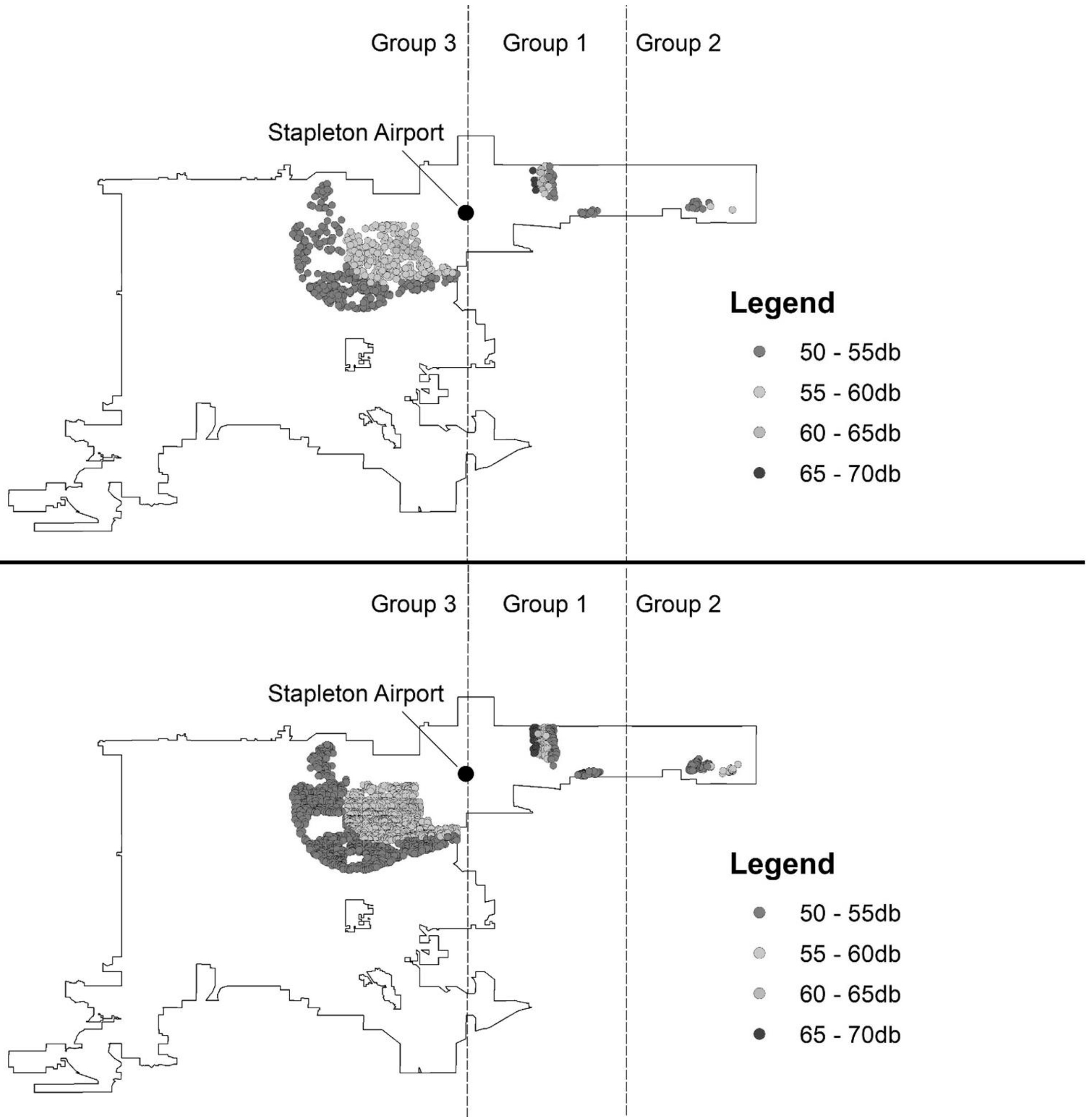
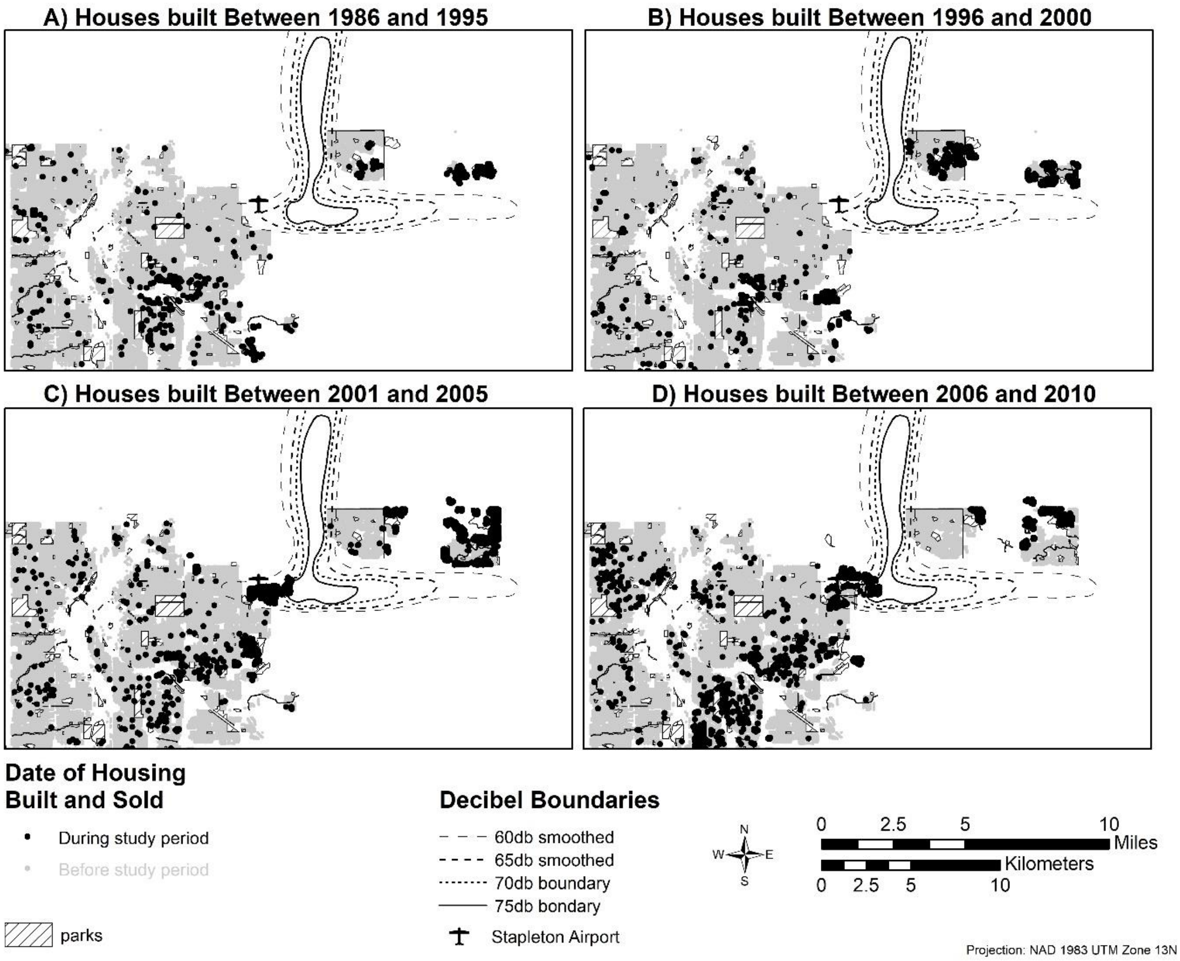


Figure 2: Pre-existing Housing and New Housing Construction around and within Stapleton Airport's Footbprint



Appendix

Table A-1: Descriptive Statistics for Difference-in-Differences Regressions

1985 Announcement	Mean	Std. Dev.	Min	Max	Count
Noise	54.700	3.349	50.003	67.620	838
Noise*Year_1985	38.506	25.064	0	67.620	838
Year_1985	0.705	0.456	0	1	838
Sales Price	82,910	58,405	6,500	1,400,000	838
Total Bathrooms	1.877	0.841	1	6	838
Age	48.321	22.518	0	103	838
Bedrooms	2.592	0.838	1	8	838
Living SF	1,759	808.4	465	10,391	838
Land SF	6,554	3,487	1,190	45,900	838

1995 Closing	Mean	Std. Dev.	Min	Max	Count
Noise	54.832	3.393	50.001	67.651	2,812
Noise*Year_1995	26.623	27.556	0	67.651	2,812
Year_1995	0.485	0.500	0	1	2,812
Sales Price	106,129	56,471	10,500	525,000	2,812
Total Bathrooms	1.924	0.845	1	8	2,812
Age	57.617	21.016	10	100	2,812
Bedrooms	2.567	0.778	1	8	2,812
Living SF	1,752	724.6	400	6,280	2,812
Land SF	6,211	1,488	1,320	18,200	2,812

Table A-1 presents the descriptive statistics for the sample of single-family property sales shortly before and shortly after the announcement of the closing (1984 and 1986 transactions in Denver), and the sample of property sales from shortly before and shortly after the closure of Stapleton Airport (1994 and 1996 transactions in Denver). These variables are used in the regressions in Table 1.

Table A-2: Descriptive Statistics, Housing Quality Regressions

Year Built: Pre-1995	Mean	Std. Dev.	Min	Max	Count
Noise	56.570	1.351	50.069	60.545	2,277
Sales Price	173,077	57,652	12,000	800,000	2,277
Land SF	5,384	1,379	3,009	14,581	2,277
Living SF	1,612	525.3	800	3,843	2,277
Bedrooms	2.989	0.603	2	5	2,277
Total Bathrooms	2.666	0.810	1	5	2,277
Year Built	1989	3.716	1985	1995	2,277
Building Age	15.060	7.208	2	32	2,277
Year	2004	6.227	1995	2017	2,277

Year Built: Post-1995	Mean	Std. Dev.	Min	Max	Count
Noise	59.182	5.876	50.035	75	6,077
Sales Price	305,318	161,107	56,000	1,000,000	6,077
Land SF	4,934	1,769	2,112	16,500	6,077
Living SF	2,202	859.3	796	5,604	6,077
Bedrooms	3.153	0.701	1	7	6,077
Total Bathrooms	3.150	0.683	1	6	6,077
Year Built	2002	3.541	1995	2014	6,077
Building Age	7.800	4.241	2	21	6,077
Year	2010	4.796	1997	2017	6,077

Table A-2 shows the descriptive statistics for the variables in the regressions in Table 4.

Table A-3: Descriptive Stats, Average Income and Percent Black Population Regressions

	Mean	Std. Dev.	Min	Max	Count
Noise	54.911	3.301	50.001	67.651	14,941
Noise*Year_1995	30.469	27.361	0	67.651	14,941
Average Income	58,965	18,179	22,439	128,974	14,941
Log of Average Income	10.936	0.318	10.019	11.767	14,941
Percent Black	16.6	14.9	0	62.0	14,941

Table A-3 shows descriptive statistics for the regressions in Table 5.

Table A-4: Balancing and Falsification Tests

Panel 1 - Balance: Housing Attributes Pre-1985 on Noise

	Group Fixed Effects	Tract Fixed Effects
Number of Bedrooms	-0.016	-0.012
	(-1.16)	(-1.13)
Number of Bathrooms	-0.010	-0.015
	(-0.52)	(-1.00)
Square Feet Living Area	4.752	-10.97
	(0.23)	(-1.23)
Square Feet Lot Size	126.4**	30.92
	(2.71)	(0.66)

Panel 2 - Falsification: Housing Price 1980 and 1984 on Noise

	Group Fixed Effects	Tract Fixed Effects
Noise*Year 1984	-0.023***	-0.018**
	(-3.41)	(-2.56)

Panel 3 - Falsification: Housing Price on Fake Noise Variable

	Pre-Post 1985	Pre-Post 1995
Noise*Post	0.003	-0.002
	(0.56)	(-1.35)

Notes: In Table A-4 Panel 1, we test the hypothesis of whether the sample of existing housing pre-announcement, in the high and low noise areas, are the same by regressing noise on the hedonic housing attributes. In Panel 2, since the actual closing announcement occurred in 1985, we consider a "fake" announcement in 1982, long before the actual announcement, in order to test for pre-trends in the effect of noise on housing prices over time. The negative statistically significant treatment effects for the "fake" announcement in Panel 2 are consistent with the continued rising levels of air traffic near the airport before the closing is announced in 1985. In Panels 1 and 2, column 1 contains results using models with the larger spatial group fixed effects, and column 2 presents results based on census tract fixed effects. In Panel 3, we use a propensity score approach to match properties that are distant from the airport so that noise is not an issue to properties that are near the airport, based on similarities in property characteristics. Then we assign a fake noise variable based on this propensity to the sample of housing units that are far from the airport, and we estimate a set of difference in differences regressions based on the 1985 announcement (column 1) and the 1995 closing event (column 2) using this fake noise variable. The statistically insignificant coefficients validate our hypothesis that noise does not impact properties that are far from the airport but are similar to the noise impacted properties in other respects. Standard errors clustered by tract. *, **, and *** mark significance at the 0.10, 0.05, and 0.01 levels, respectively.