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Authors	Jeffrey P. Cohen, Cletus C. Coughlin, Jonas Crews, and Stephen L. Ross
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Federal Reserve Bank of St. Louis, Research Division, P.O. Box 442, St. Louis, MO 63166

Negative Externalities and Real Asset Prices:

Closing of Stapleton Airport in Denver and Effect on Nearby Housing Markets

Jeffrey P. Cohen
Professor of Real Estate and Finance
University of Connecticut
Jeffrey.Cohen@uconn.edu

Cletus C. Coughlin
Senior Vice President and Chief of Staff
Federal Reserve Bank of St. Louis
coughlin@stls.frb.org

Jonas Crews
Senior Research Associate
Walton Family Foundation
jcrews@wffmail.com

Stephen L. Ross
Professor of Economics
University of Connecticut
Stephen.L.Ross@uconn.edu

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Abstract: The closing of a busy airport has large effects on noise and economic activity. We examine the effects of Stapleton airport's closing on nearby, Denver housing markets. We find evidence of immediate anticipatory effects on prices upon announcement of the closing, but no price changes at closing likely because it was widely anticipated. However, we find that high income and white households delayed moving into these locations until after the airport's closing. Also, developers upgraded the quality of houses being built after closing. Further, post-closing, these demographic and housing stock changes had substantial effects on housing prices.

JEL codes: R31, R41

Keywords: Airport noise, housing prices, airport closing, anticipatory effects, dynamic price effects

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Introduction

Local amenities or externalities can affect the price of physical or real assets. Housing is probably the real asset most susceptible to the impact of local externalities, and airplane noise represents a significant negative attribute associated with neighborhoods near airports. Many studies have examined how airport noise impacts housing prices, but most of these studies are cross-sectional and few have examined the effects of closing an existing airport. We use the timing of events surrounding the closing of Stapleton airport in Denver to examine the impact of airport noise on housing prices. We first examine the immediate effects of the announcement and the eventual closing. Then, we examine how the closing affected the surrounding neighborhoods, and through those changes the long-run trajectory of housing prices.

Studies exploring the spatial distribution of airport noise face a number of challenging issues. First, adequate data is an issue. Especially challenging is pinning down the noise contours. Second, the changing distribution of noise likely leads to a disequilibrium in the housing market; adjustments in prices and ownership of property take time to produce a new equilibrium. Frequently, the changes in the spatial distribution of noise are small and can be difficult to detect. Third, adjustment in prices and ownership can begin in anticipation of future changes in noise. Thus, it is not always entirely clear when homeowners and potential homeowners begin the adjustment process. Finally, redevelopment in the formerly noisy areas can occur, implying potential endogeneity of house characteristics and shifts in income and demographics in those neighborhoods. Large-scale changes in noise exposure, which can be generated by airport closings, provide a better opportunity to identify effects on prices and neighborhoods and to examine the potentially large dynamic effects of closing on housing prices in the long-run.

We develop a unique dataset for addressing these issues. We combine data that we have scraped from the 1980s in the Denver land records with more recent data provided by the

Denver assessors' office. The dataset covers single family housing sales in the area of Stapleton airport for several years in the 1980s, and between 1990-2016. We also draw on the Home Mortgage Disclosure Act staring in 1990 to examine demographic changes in the composition of homebuyers.

The future closing of Stapleton airport in Denver was announced in 1985, with a permanent closing that occurred in 1995. We find some evidence of an immediate anticipatory effect on relative housing prices in the noisiest locations around Stapleton upon the announcement of plans to close the airport, but no discontinuity in prices at the time of its permanent closing likely because the closing was widely anticipated and prices adjusted smoothly as the closing date approached. However, given the costs of living near an airport even if it will close soon, we test for and find that on average high income and white households avoided moving into the noisiest locations until after the actual closing. Similarly, developers did not shift their pattern of homebuilding towards nicer/larger houses until after the airport's closing, or at least there was an acceleration of such effects after closing. The resulting changes in neighborhoods, which arise as incomes rise and larger houses are built, is associated with rising housing prices over time, even though we examine effects on pre-existing housing that was built before the closing of the airport.

The remainder of this paper proceeds as follows. First, we describe the history of Stapleton Airport in Denver, followed by a survey of the literature on the impacts of airport noise on house prices. We then describe our empirical approach, present descriptive statistics of the data, and summarize our estimation results. Finally, we conclude with a recap of our findings and suggest some directions for future research.

Background: Stapleton Airport in Denver[1]

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 was located in 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), which opened in February 1995. Simultaneously, Stapleton ceased operations, which has been followed by a substantial redevelopment of the former airport land. This redevelopment is continuing to this day.

Given the uniqueness of this airport closure and redevelopment, Stapleton is an ideal setting to examine how airport noise has impacted real asset prices. While there is a significant literature on airport noise and house prices, the closure of Stapleton provides us with a quasi-experimental setting to identify the impacts of noise on real asset prices. Further, the Stapleton closure provides some insights into the general equilibrium effects of the presence of an airport because we can observe the neighborhood changes that arose following the closure and the changes in housing prices that followed these neighborhood changes. A brief overview of the existing literature is provided below, followed by a detailed discussion of our approach and unique dataset.

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

Literature Review

The vast majority of economics research on aircraft noise has focused on the costs of airport noise (or the benefits of reducing noise), especially on the extent to which this noise affects property values.[2] Two surveys of this literature have been provided by Nelson (1980; 2004). Such estimates can be key inputs in cost-benefit assessments of proposals to reduce noise. In Nelson (1980) the author summarizes key aspects of the underlying hedonic price model and the results of thirteen studies.[3] The range of noise discounts was 0.4 to 1.1 percent per decibel, with a common discount of 0.5 to 0.6 percent per decibel.[4] In his more recent review, Nelson (2004) finds noise discounts similar to his previous study. One difference is that the noise discount in Canada tends to be larger than in the United States; estimates indicate a noise discount of 0.8 to 0.9 percent per decibel.

Model specification also plays a role in contributing to differential results. Nelson (2004) noted that noise discount studies were beginning to employ other analytical methods, such as spatial econometric methods and quasi-experimental designs, which raises the possibility of different results. Further, many of the early hedonic studies on airport noise were cross-sectional studies. While cross-sectional hedonic regressions can generate estimates for the valuation of non-traded environmental goods, such as airport noise, they have shortcomings

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[2] Another approach to assess costs, which is infrequently used for airport noise, is based on surveys of those affected or likely to be affected by noise. Strategic response bias and sample selection bias are key problems with surveys. For examples of contingent valuation of airport noise, see van Praag and Baarsma (2005) and Feitelson, Hurd, and Mudge (1996). For an example of this approach in the context of noise in general, see Weinhold (2013).

[3] Nelson (1980) notes that residential housing values reflect supply and demand. Thus, the implicit characteristics should as well. When the market is not in equilibrium, then the estimates are likely suspect for policy decisions. Nelson also notes the importance of controlling for airport accessibility. Failure to do so likely results in understated noise cost estimates. More recently, the implications of disequilibria have been examined by Coulson and Zabel (2013).

[4] Another literature review by Schipper, Nijkamp, and Rietveld (1998) of 19 studies found much variation of the estimates across studies.

that can produce inaccurate estimates of an individual's willingness to pay because housing unit and neighborhood unobservable may correlate with airport noise.

To deal with the shortcomings of cross-sectional hedonic regressions, some studies have relied on quasi-experiments. For example, Boes and Nüesch (2011) use a change in flight regulations for the Zurich Airport that resulted in a new noise pattern allowing for the inclusion of location controls that reduce the problem of omitted variable bias. In Boes and Nüesch (2011), it is reasonable to assume that the treatment (i.e., change in noise levels) was assigned randomly to a set of houses. As noted by Almer, Boes, and Nüesch (2017), this approach is not without problems. Econometric approaches, such as difference-in-differences methods, estimate capitalization effects, but the connection to meaningful welfare measures and willingness-to-pay is not clear. Second, especially in the context of the housing market, if the market is not in equilibrium, then the estimated capitalization effect may be biased either upward or downward depending upon how neighborhoods evolve over time in response to the shock.

In a second study of spatial changes in noise patterns, Cohen and Coughlin (2009) examine changes in the level of airport noise in neighborhoods near Hartsfield-Jackson Atlanta International airport. Declining levels of noise were associated with rising house prices. Consistent with standard findings, houses in noisier areas (>65 DNL) sold for approximately 20% less than houses subjected to lower amounts of noise. In addition, the noise discount tended to increase over time suggesting that the surrounding neighborhoods might be transitioning to a new equilibrium with higher neighborhood quality and higher prices.

McMillen (2004) examines a proposed expansion of Chicago's O'Hare Airport. The plan examined was for the construction of a new runway and the reconfiguration of seven existing runways. He noted that airports were becoming less noisy over time due to the introduction of less noisy new aircraft and the reduction in night flights. Based on an existing noise contour in

1997 and projected noise contours after the expansion/reconfiguration, McMillen estimated that the area subjected to severe noise would decline from roughly 57 square miles in 1997 to 27 square miles after the changes. In 1997 home values within a 65 dB noise contour band were about 9 percent lower. Given the new noise contours, McMillen estimated that home values could rise by as much as $284.6 million.

Mense and Kholodilin (2014) focused on the impact of expectations of aircraft noise resulting from the construction of the new Berlin-Brandenburg Airport.[5] Using spatial econometric methods, the authors found that affected properties are likely to experience a 9.6 percent decline in value, with lower (higher) flight altitudes generating larger (smaller) absolute discounts.

The adjustments in the rental housing market after a much larger change in aircraft noise exposure were examined by Almer, Boes, and Nüesch (2017). After an unexpected change in flight regulations, they found that the restoration of rents to a new equilibrium took about two years. This new equilibrium is characterized by a constant mark-up for the apartments subjected to less noise relative to those apartments subjected to more noise. They conclude that a flexible difference-in-differences approach with time-varying treatment effects is very useful in identifying the adjustment process.

The approach in our paper has much in common with the approach in Almer, Boes, and Nüesch in that we examine how the effect of exposure to different levels of noise changes after specific events, although there are some important differences. We examine single-family owner-occupied housing (opposed to apartments), and we consider an even larger shock due to an announcement of an airport closing and the eventual closing. The unique aspects of these

[5] A related article that focuses on impact of noise expectations is by Jud and Winkler (2006). They estimated the relationship between the distance to a regional airport in North Carolina and housing prices after FedEx decided to locate an air-cargo hub at the airport. Their estimates included both the anticipated noise discount and the impact of the job-creating effects of the decision.

events in Denver, together with our data that extends back to the 1980s (which is uncommon in property-level hedonic analyses that rely on commercial sources of such data), enable us to examine the broader issue of redevelopment, how housing quality changed after the closure of the old airport, and the long-run impact of these changes on housing prices.

Empirical Approach

In order 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 the closing of Stapleton, and estimate for each of these events a separate hedonic housing price model, as in Rosen (1974). 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 effect of noise on housing prices (y_{itl}). This approach leads to the following model (assuming a semi-logarithmic functional form):

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

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, and β_3 captures the effect of the event on the relationship between airport noise and housing prices.

This model does not necessarily include geographic controls because the variation in noise with the sample primarily arises across traditional geographic categories, like census tracts, and so equation (1) is estimated so that the cross-sectional relationship between prices and noise can be observed along with the effect of the event on that relationship. We estimate a second set of models that includes census tract fixed effects.

$$Log(y_{itlc}) = \beta_0 X_{it} + \beta_1 N_l + \beta_2 E_t + \beta_3 N_l E_t + \delta_c + \varepsilon_{itlc} \quad (2)$$

where the census tract fixed effects are represented by δ_c in order to examine whether the difference-in-differences estimates are robust to the inclusion of neighborhood controls.

Next, we look at the home sales during the years leading up to and following the closing of Stapleton in order to regress attributes associated with those sales, either attributes of newly built housing, or the average demographics of homebuyers in a housing unit's census tract. Specifically, for housing attributes, we estimate separate models before and after the closing and compare the estimates on noise β_{1D} across the two time periods D.

$$X_{itl} = \beta_0 + \beta_{1D} N_l + \delta_{cD} + \gamma_{tD} + \varepsilon_{itl} \quad (3)$$

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 indicates 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.

On the other hand, 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 Home Mortgage Disclosure Act data down to the census tract. 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

$$Z_{ct} = \beta_0 + \beta_1 N_l + \beta_2 E_t + \beta_3 N_l E_t + \delta_c + \gamma_t + \varepsilon_{itlc} \quad (4)$$

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.

Finally, we consider whether the observed changes in the attributes of new housing being built and sold and the demographics of homebuyers in general have an influence on housing prices in the period following the closure. 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 attributes of new homebuyers in these locations. For this analysis, we restrict the sample to housing units that were built before the 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.

$$Log(y_{itlc}) = \beta_0 X_{it} + \beta_1 N_l + \beta_2 \bar{X}_{ct-3} + \beta_3 \bar{Z}_{ct-3} + \delta_c + \gamma_t + \varepsilon_{itlc} \quad (5)$$

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

Standard errors are clustered at the census tract level for all models.

Data

As indicated earlier, our data come from several sources. First, the Denver assessor provided sales data from 1990 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 CoreLogic property characteristics data. 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 (HMDA) data that we averaged for each tract. 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 out 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 are based on housing units that are predicted to have been exposed to 50 dB or higher levels of noise based on our noise contour interpolations.

We present several tables of descriptive statistics for our data. Table 1 shows the descriptive statistics for the variables used in the 1984-86 and 1994-96 difference-in-differences regressions. Since the closing announcement occurred in 1985 and the airport closed in 1995, we compare sales in 1984 to 1986, and 1994 to 1996. In Table 1, Year_1985 is a dummy variable that equals 1 if a sale occurred in 1986 and 0 if in 1984; and Year_1995 is a dummy that equals 1 if a sale occurred in 1996 and 0 if in 1994. We did not scrape sales of housing units that sold in 1985, and for consistency we omit sales from 1995. We were able to obtain information on 838 arms-length sales in our 1984/86 sample and the assessor's data contained 2,812 arms-length sales 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. In these regressions 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.

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

1985 Announcement	Mean	Std. Dev.	Min	Max	Count
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
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

1995 Closing	Mean	Std. Dev.	Min	Max	Count
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
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

Note: The top panel of Table 1 consists of a random sample of residential real property sales data for the years 1984 and 1986; and the bottom panel is for the years 1994 and 1996.

Table 2 shows the descriptive statistics for the average income and percent black population regressions. These data come from individual HMDA data that we have obtained at the tract level for the years 1990 onward and 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 in 1995 was again approximately 55 dB, which is not surprising since the HMDA home purchase data captures most of the housing transactions.

Table 2: Descriptive Stats, Average Income and Percent Black Population Regressions

	Mean	Std. Dev.	Min	Max	Count
Average Income	79,210	31,067	22,439	176,127	31,715
Log of Average Income	11.202	0.399	10.019	12.079	31,715
Percent Black	14.0	13.4	0	62.0	31,715
Noise	55.001	3.407	50.001	67.703	31,763
Noise*(Year ≥ 1995)	45.817	20.830	0	67.703	31,763

Table 3 contains descriptive statistics for the housing quality analyses. 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 3, 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). Between 1985-95, the typical house was exposed to 56.6 dB of noise, while 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 to 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.

Maps of the area under consideration in this study (Denver County) are presented in Figures 1a and 1b. In these maps, one can see the locations of the 1984 and 1986 sales in Figure 1a, as well as the associated extrapolated/interpolated noise level for each property. Figure 1b shows the sales in 1994 and 1996 as well as the noise level exposure based on the extrapolated/interpolated 1995 noise data. In viewing these maps, we identify 3 clusters of properties (loosely referred to as "groups"), which we control for using fixed effects in any of our estimations that do not include census tract fixed effects.

Table 3: 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 of Sale	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 of Sale	2010	4.796	1997	2017	6,077

Figure 1a – Random Sample of Denver Single Family Residential Property Sales and Noise Exposure, 1984 and 1986

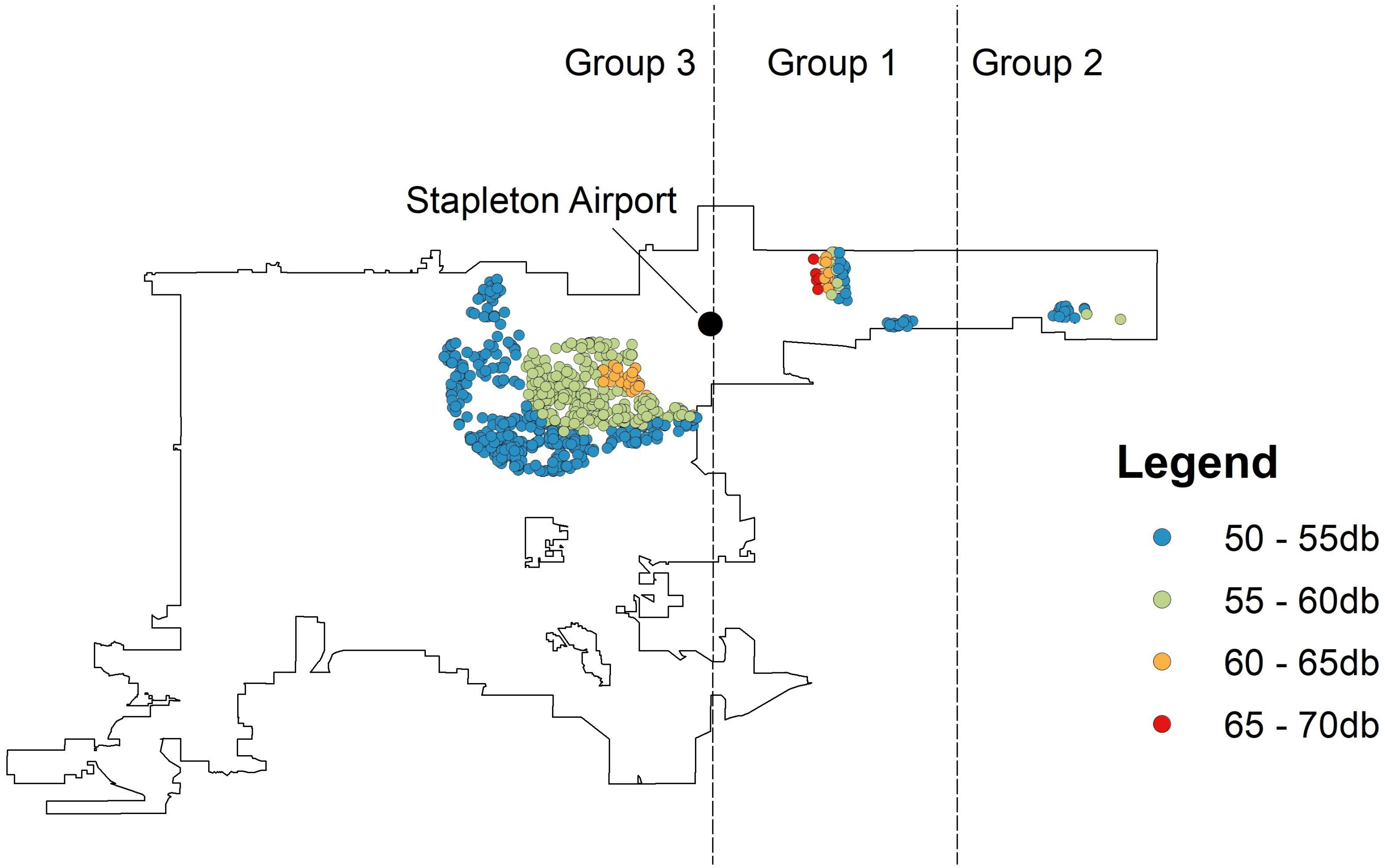
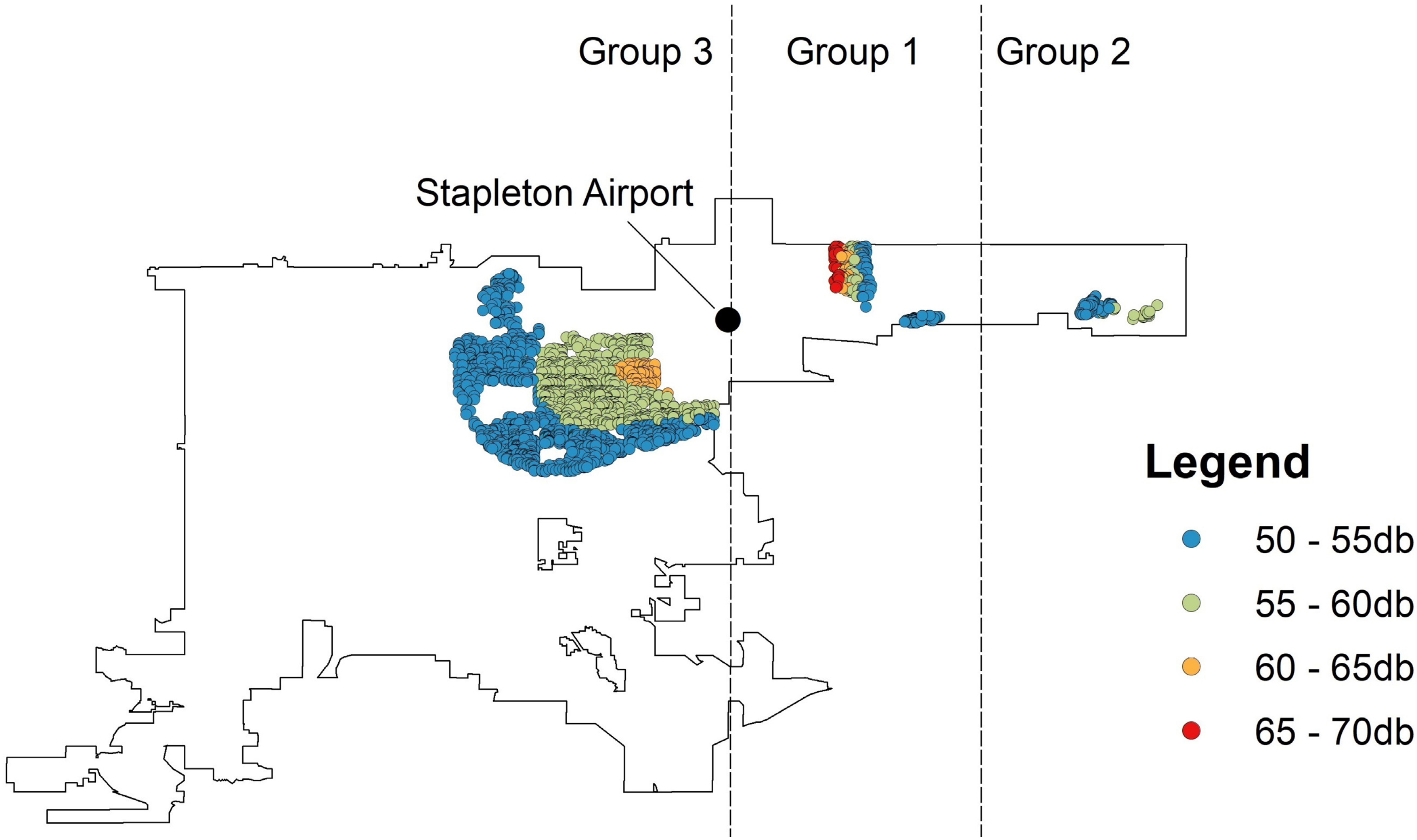


Figure 1b – Denver Single Family Residential Property Sales and Noise Exposure, 1994 and 1996



Results

The difference-in-differences results are presented in Table 4. The first two columns, using data for 1984 and 1986 sales, are the results for the 1985 announcement with either tract (column 1) or “group” 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, but 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. This lack of an immediate change in prices upon closing is not 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 prior to closing), those estimates are statistically insignificant and for the preferred tract fixed effects model very close to zero.

Table 4: Difference-In-Differences Results - 1985 Announcement and 1995 Closing

Dependent Variable: Log of Sales Price

	1985 Announcement		1995 Closing	
	Tract Fixed Effects	Group Fixed Effects	Tract Fixed Effects	Group Fixed Effects
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)
Noise	-0.024**	-0.025**	-0.004	-0.014
	(-2.26)	(-2.62)	(-0.58)	(-1.12)
Noise*Year_1985	0.017*	0.016	-	-
	(1.72)	(1.49)	-	-
Year_1985	-0.873	-0.789	-	-
	(-1.61)	(-1.41)	-	-
Noise*Year_1995	-	-	-0.002	-0.001
	-	-	(-0.46)	(-0.33)
Year_1995	-	-	0.331	0.296
	-	-	(1.67)	(1.16)
Group 1	-	-0.100	-	-0.043
	-	(-1.24)	-	(-0.32)
Group 2	-	0.135*	-	0.350**
	-	(1.75)	-	(2.79)
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	838	2,812

Notes: T statistics in parentheses. Standard errors clustered by tract. *, **, and *** mark significance at the 0.10, 0.05, and 0.01 levels, respectively.

Next, we test the hypothesis that "better" houses were built after the old airport closed and the land began to be redeveloped. These models all include census tract fixed effects so that we are comparing housing that was built in similar locations before and after the closing of the airport. Table 5 presents these estimates over 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 relation with noise for a sample of sales 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 way, and as a result the quality of the total housing stock in the areas that formally had high levels of noise is improving over time.

Table 5: Regressions of Housing Characteristics

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: 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.

We next consider how demographics of homebuyers changed after the closing of Stapleton. Since our HMDA data only begins in 1990, we just consider home purchases and mortgage borrowers between 1990 and 2000 so that our data is centered around the closing date. As with the housing attribute regressions, all models include census tract fixed effects. As with the housing characteristics, properties that sold in 1995 or later exhibit a positive, statistically significant impact on average income and negative impact of share black in locations with higher noise. However, the magnitudes of the estimated effects are modest. Looking at the interaction coefficients, a 5 dB increase 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 increase above the means share black among homebuyers of 14 percent.[6]

Table 6: Regression Results for Properties Sold Between 1990 and 2000

All regressions include tract fixed effects

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: T statistics in parentheses. All specifications include year fixed effects. Standard errors clustered by tract. *, **, and *** mark significance at the 0.10, 0.05, and 0.01 levels, respectively.

Finally, we explore the effect of changes in housing quality through new building and demographics through new homebuyers on the dynamic process of housing price adjustment in Table 7. Specifically, we present hedonic regressions that include controls for the average income of buyers over the preceding 3 years in the tract and the square feet of living area of newly built housing in the preceding 3 years. The sample is restricted to include only post-closing sales of housing that was built prior to the closing of the airport so that changes in the unobservables of the housing stock after closing cannot influence the estimated price levels.

[6] In Table 6, Year_1995 is an indicator variable that equals 1 when a sale occurred between 1995-2000 (i.e., after the closure of the airport), and 0 if the sale occurred between 1990-1994 (before the closure). In contrast, Year_1995 in Table 4 refers only to sales that occurred in 1996 (one year after the 1995 closure).

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. As above, all regressions include tract fixed effects. We find positive effects of both variables. Both the building of larger houses and the fact that higher income households are moving into these locations imply higher housing prices within census tracts over time.

The regression is log-log so that the coefficient 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 column 3, a 10 percent increase in the average income of recent home buyers is associated with a 4.4 percent increase in housing prices, while 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.

Table 7: Hedonic Model for Post-1995 Transactions
Dependent Variable: Log of Sales Price

	Tract Fixed Effects in all regressions		
	Including 3-Year Avg. Living SF of Tract	Including 3-Year Avg. Income of Tract	Including 3-Year Avg. Income and Living SF
Noise	-0.003***	-0.003***	-0.003***
	(-4.29)	(-4.44)	(-4.56)
Log of Bedrooms	0.086***	0.091***	0.091***
	(15.39)	(16.63)	(16.61)
Log of Total Bathrooms	0.075***	0.072***	0.071***
	(14.91)	(14.54)	(14.44)
Log of Land SF	0.133***	0.128***	0.127***
	(19.55)	(19.09)	(19.00)
Log of Living SF	0.388***	0.390***	0.389***
	(68.35)	(69.84)	(69.73)
Log of 3-Year Avg. Living SF of Tract	0.113***	-	0.157***
	(7.22)	-	(10.19)
Log of 3-Year Avg. Income of Tract	-	0.428***	0.437***
	-	(37.18)	(37.89)
Constant	6.482***	2.713***	1.528***
	(49.53)	(19.10)	(8.33)
R-Squared	0.797	0.803	0.804
Observations	41,867	41,867	41,867

Notes: T statistics in parentheses. Standard errors clustered by tract.
*, **, and *** mark significance at the 0.10, 0.05, and 0.01 levels, respectively.

Conclusion

This paper examines the short and long-run implications of the closing of Stapleton airport in Denver. We first use a difference-in-differences approach that includes an interaction term between the continuous level of noise from the airport and an indicator for an event (the announcement of the new airport land acquisition in 1985, implying the future closure of Stapleton; and the actual closure of Stapleton in 1995). We find that residents react immediately after the 1985 announcement, and the negative effects of noise levels on property values is eroded substantially. We find no effect after the airport closes in 1995, which is not unexpected given that prices had a decade to adjust to the closing and near the date of closing the impact of noise on prices had already fallen to zero.

Next, we explore longer run impacts by examining changes in the composition of the housing stock and 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 homebuyer was black population fell in the areas that were formerly noisy. Finally, we exploit these changes at the neighborhood level examining whether the composition of new homebuyers and newly built housing units has dynamic effects on housing prices after 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.

While there have been many past studies of how airport noise impacts house prices, our study is unique in several ways. First, we develop additional data (by interpolating noise contours; scraping older 1980s data from the Denver assessor’s database; and merging the later years of data with HMDA demographic information) allowing us to conduct difference-in-differences analyses that demonstrate relatively complete anticipation of the immediate effect of Stapleton’s closing on housing values by the time that the closing actually occurred. Second, given the nature of the event, we are able to examine the long-run impacts on housing prices through migration of new home buyers and the decisions of builders concerning the size and quality of housing units. Real asset prices (in the residential context) depend critically on the value of environmental amenities and disamenities. Further, the sorting of households over these amenities can change the composition of neighborhoods reinforcing the price effects of the surrounding environment. Past research has struggled to consider these longer run, general equilibrium impacts of environmental disamenities, both overall and in the context of airport noise. Our study provides unique evidence on the importance of these equilibrium effects.

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