The Closing of a Major Airport: Immediate and Longer-Term Housing Market Effects

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Abstract: The closing of a busy airport has large effects on noise and economic activity. 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 airport closure, more higher income and fewer black households moved into these locations, and developers built higher quality houses. Finally, post-closing, these demographic and housing stock changes had substantial effects on housing prices, even after restricting the sample to sales of pre-existing housing.

Keywords: Airport noise, housing prices, airport closing, anticipatory effects, long-term effects, neighborhood change, dynamic price 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 have independent effects on price (Sieg, Smith, Banzhaf, and Walsh 2004; Walsh 2007;

[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.

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]

To study the long-run effects of amenities on housing prices, we exploit the large change in location desirability arising from the closing of Stapleton Airport in Denver and the elimination of the associated airplane take-off and landing noise impacts on surrounding properties. Many studies have examined how airport noise impacts housing prices, but most of these studies are cross-sectional and virtually none have examined the potentially large effects of closing an existing airport. Almer, Boes, and Nüesch (2017), Boes and Nüesch (2011) and Cohen and Coughlin (2009) examine the effects of changes in flight regulations or paths that reduced airport noise finding short-run positive effects on housing prices.[5] In terms of very large changes in noise levels, Mense and Kholodilin (2014) examine the impact of expectations of aircraft noise resulting from the construction of the new Berlin-Brandenburg Airport, and Jud and Winkler (2006) estimate the effect of the distance to a regional airport in North Carolina after FedEx decided to locate an air-cargo hub at the airport. However, these two

[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)
[5] For a recent cross-sectional analysis, see McMillen (2004). For detailed literature reviews see Schipper, Nijkamp, and Rietveld (1998) and Nelson (1980; 2004).

studies are based on expectations of future noise and so may not detect the effects of the neighborhood changes that are likely to occur over time. From such studies, it is difficult to know whether households are simply anticipating changes in noise levels or instead are predicting the resulting changes in neighborhood composition and the overall expected impact of those changes on neighborhood quality.[6]

An additional paper examining the impact on housing prices of an airport closure is Thanos, Bristow, and Wardman (2015), which focuses on the closure of the Athens International Airport. While the paper highlights the role of residential sorting in explaining ever-larger negative effects on housing prices as aviation noise increases, little evidence is provided on long-run neighborhood changes. A key finding is that a particularly noisy area showed a price stigma from airport noise during the first year after the airport ceased operations.

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 recognizing that adjustments in prices can begin in anticipation of the future changes in noise levels. Then, we examine how the closing affected the surrounding neighborhoods through both the attributes of newly constructed homes and the demographics of homebuyers in these

[6] Another approach to assess costs is surveys of those affected or likely to be affected by noise. For examples of contingent valuation of airport noise, see van Praag and Baarsma (2005) and Feitelson, Hurd, and Mudge (1996), or noise in general, see Weinhold (2013). While strategic response bias and sample selection bias are key problems with surveys, such an approach might be valuable to uncovering whether households consider potential neighborhood composition changes when evaluating their willingness to pay to eliminate airport noise.

neighborhoods. Finally, we examine the relationship between the demographic and housing stock changes and the price level based on the sales of pre-existing housing.

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 and 2016. We also draw on the Home Mortgage Disclosure Act (HMDA) data starting 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. Our failure to identify price effects at closing might arise because the closing was widely-anticipated and prices adjusted smoothly as the closing date approached. To test for this, we estimate models that document any increases in prices in areas exposed to high levels of airport noise prior to the closing of the airport.[7] However, we find no evidence of gradual increases in prices between announcement and closing. Therefore, we conclude that the direct effect of closing on housing prices

[7] Given our quasi-experimental strategy, it is impossible for us to separate gradual increases in prices between announcement and closing that could have arise from anticipation from other secular increases in housing price within the area. However, such an adjustment process is consistent with Bishop and Murphy's (2019) analysis where households choose houses based on the future expected stream of amenities which in our case would begin when the airport closes. Note that Bishop and Murphy (2019) also focus on estimating willingness to pay for amenities while our analysis focuses entirely on the amenity effects on market housing prices.

was modest in magnitude and occurred immediately after the announcement of the closing.

However, given the short-run costs of living near an airport even if it will close soon, the indirect effects of closing that arise through changes in the composition of these neighborhoods may occur primarily after the closing. Therefore, we test for and find that on average, more higher income and non-black households tended to move into the noisiest locations after the actual closing but not earlier. Similarly, developers appeared to delay the shift in their pattern of homebuilding towards nicer/larger houses (houses that were similar to the nearby pre-existing housing that was exposed to less airport noise) until after the airport's closing, or at least there was an acceleration of such effects after closing. The resulting changes in neighborhoods 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.

To validate our event study approach, we conduct several additional analyses. First, we demonstrate that the housing stock pre-1985 was similar between locations that were exposed to high levels of airport noise and those exposed to more modest levels of airport noise. Second, consistent with the growth of flight activity at Stapleton airport during this period, we find that areas exposed to more noise based on our static measure of noise levels were associated with falling prices over time prior to the announcement of the airport, which were reversed following the announcement. Finally, we conduct a falsification test re-estimating our event study models replacing our sample of housing sales with alternative sales that are located away from the airport and closely match the housing unit in our sample. Using housing units that have nearly the same propensity score in terms of likelihood of being exposed to airport noise, we find no relationship between changes in housing price over the event years and noise level for these falsified transactions that were clearly not exposed to airport noise.

The remainder of this paper proceeds as follows. First, we describe the history of Stapleton Airport in Denver. 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[8]

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 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; simultaneously, Stapleton ceased operations. Subsequently, the 7.5 square miles,

[8] 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).

which is approximately fifteen minutes from downtown Denver, has been in various stages of redevelopment that is continuing to this day.

The urban, in-fill redevelopment was, at one time, the largest ever in the United States.[9] 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 area in 2002; today, there are more than 32,000 residents living in roughly 14,000 homes, 9000 single-family houses and 5000 rental units.

Given the uniqueness of this airport closure and redevelopment, Stapleton is an ideal setting to examine how airport noise has impacted single-family residential real estate 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 estate 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.

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

Empirical Approach

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 we estimate for each of these events as 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):

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

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 neighborhoods or census tracts within these neighborhoods.

Next, we look at the home sales during the years leading up to and following the closing of Stapleton 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.

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

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.

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 HMDA 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:

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

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.

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 sold housing units that were built at least three years 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.

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

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 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 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 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 HMDA data that we averaged for each tract dropping mortgages not designated for owner-occupancy to assure that purchaser and the new resident are the same.

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. 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 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 A-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. For the neighborhoods in which we also had noise data (either actual or interpolated/extrapolated), 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. 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 A-2 in the Appendix 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 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 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.

In the Appendix, Table A-3 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 census 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 owner-occupied housing transactions.

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 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. In viewing these maps, we identify 3 clusters of properties (loosely referred to as “broader neighborhoods”), which we control for using fixed effects in all estimations that do not include census tract fixed effects.

[Figure 1 Here]

Results

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 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 between 1984 and just prior to closing in 1994, we 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 interpret 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. 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.

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. While statistically significant, the trend coefficients are very near zero, so that over the 10-year period the estimates imply only a 0.2 percent increase in housing prices. Similarly, while some individual year to year changes are sizable (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 at most minimal evidence of any gradual increase in prices between the announcement and the actual closure. Accordingly, we are forced to conclude that the direct effects of closure on prices through reducing airport noise were quite modest and arose relatively quickly after the announcement of the planned closure.

[Table 2 Here]

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 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 3 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 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 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 3 Here]

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 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.[10]

[Table 4 Here]

Finally, we explore the effect of changes in housing quality through new building and changes in demographics through new homebuyers on the dynamic process of housing price adjustment in Table 5. Specifically, in Panel 1, 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 before 1992 (i.e., substantially before the closing of the airport in 1995), so that changes in the unobservables of newly built housing after closing cannot influence the estimated price levels. 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 the locations that were previously noisy imply higher housing prices over time.

[10] In Table 3, 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).

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.

[Table 5 Here]

Model Validation

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[11] (i.e., before the announcement) where we regress the housing attributes of these pre-1985 sales on the noise level. Specifically, we test

[11] 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.

whether the sample of existing housing pre-announcement in the high and low noise areas are the same. The results are shown in panel 1 of Table 6. The estimates arising from separately regressing each of bedrooms, bathrooms, living area and lot size on noise are all modest in magnitude and statistically insignificant in the tract fixed effects model (column 2), while the lot size is the only attribute with significant coefficient on the noise variable in the “group fixed effects” models. Overall, these balancing test results support the null hypothesis that the sample of houses sold before the 1985 announcement are not significantly different in the high and low noise areas.

[Table 6 Here]

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. The effects are shown in Panel 2 of Table 6. Unlike the effect of the 1985 announcement date on prices in noisy areas that is positive, in this falsification test we find a negative relationship between the “fake” event and the effect of noise on housing prices. This negative finding in not surprising. During this period, the amount of air travel in and out of Stapleton Airport was growing substantially almost certainly leading to larger negative effects in the places that were most exposed to airport noise. Given our static measure of airport noise levels, the increases in activity over time would tend to increase the price discount associated with our measure of noise.

Finally, we conduct an alternative falsification test where we identify transactions that are very similar to the transactions that occurred near the airport. 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. 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 Panel 3 of Table 6 and do not indicate any relationship between changes in housing prices across the event year and noise for these housing units that were not actually exposed to airport noise.

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 are eroded substantially. We find no effect after the airport closes in 1995. In fact, we find minimal evidence of faster housing appreciation between the announcement and the closing in areas exposed to the most airport noise. As a result, we conclude that the direct effects of the closing were modest in magnitude and arose primarily in the year following the announcement.

Next, we explore longer run impacts by examining 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 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/extrapolating 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 direct effect of Stapleton's closing on housing values at the time of the announcement. 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. Residential property values 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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Table 1: Hedonic Diff-In-Diff 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
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)
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)
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	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. Column 1 is the tract fixed-effects results and Column 2 is the group fixed effects results. In contrast, the significance of the 1995 actual closure treatment effects disappears in Columns 3 and 4, implying the closure was fully anticipated. T-statistics in parentheses. 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 between 1984 and 1994

Panel 1 - Year Linear Trends

	Group Fixed Effects	Tract Fixed Effects
Noise*Trend	0.0002*	0.0002***
	(1.99)	(2.83)

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: Panel 1 demonstrates that there was a positive and significant impact of noisier locations over time on house prices, likely due to the anticipation of the future (post-closing) lower noise levels in these areas. Panel 2 results indicate that with a nonparametric trends analysis, due to expectations of the 1995 closure, changes in house prices in the noisier areas were anticipated long before the closure date. 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

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 on noise, for the period leading up to the closure of Stapleton Airport (1985-95) and after the closure (Post-1995). For all 4 characteristics (Bedrooms, Total Bathrooms, Living SF, and Land SF), the corresponding regressions indicate that greater noise was associated with fewer bedrooms, bathrooms, living area, and land area before the closing. But after the closing the negative correlations between the formerly noisy areas and the property characteristics disappear (i.e., they are negative and insignificant for bedrooms, total bathrooms, and living SF), and there is a positive and statistically significant correlation with land SF and property locations in the previously noisy areas after the closure. 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 at individual properties in the corresponding tracts. The difference-in-differences estimations yield treatment effects that imply average incomes were higher in the formerly noisy areas after the 1995 closure, and smaller percentages of the population that were Black lived in the formerly noisy areas after the 1995 closure. 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.

Table 5: 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)

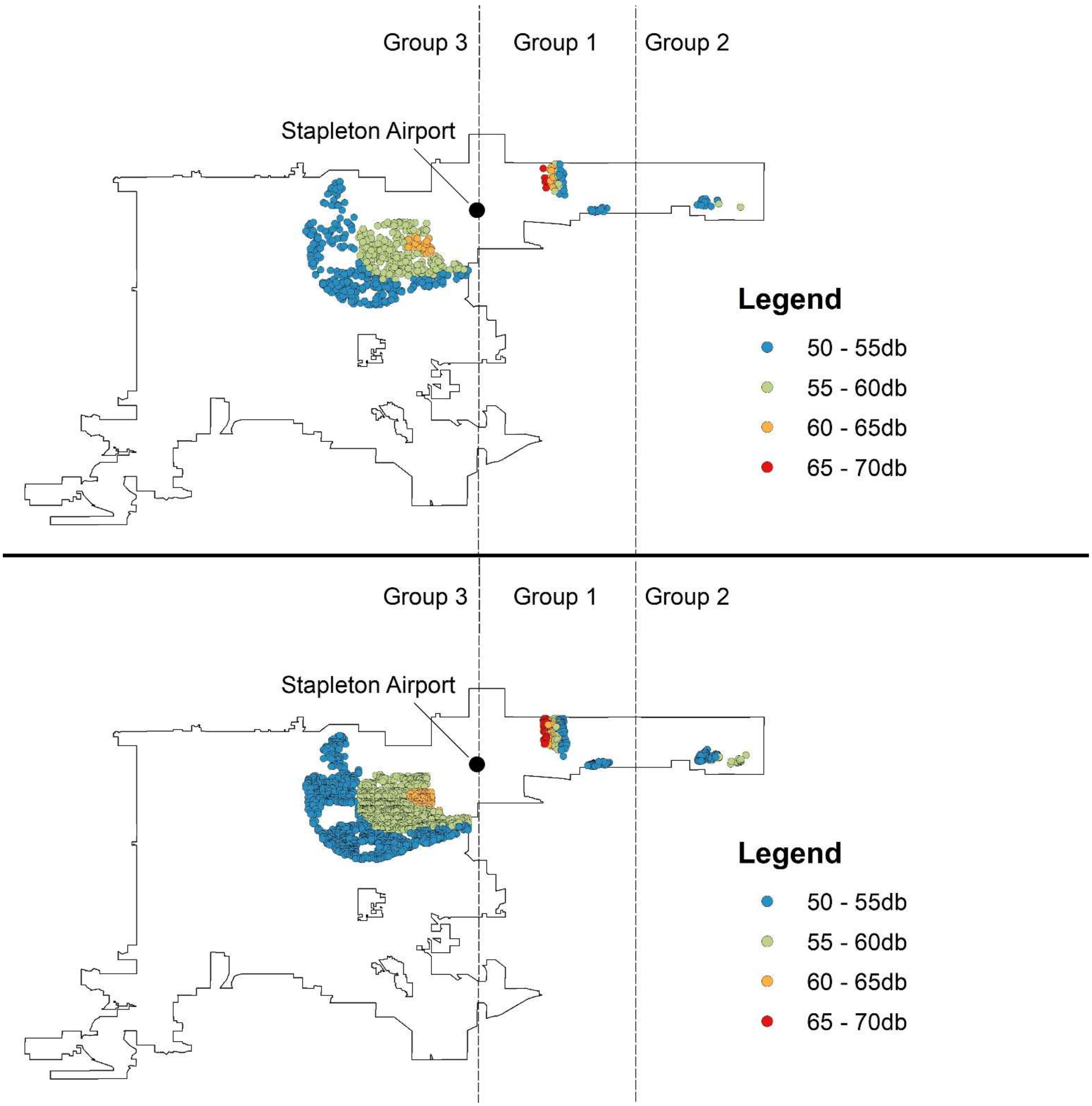
Notes: Table 5 examines the dynamic (i.e., long-run) adjustment process of prices in response to property size and tract-level income. The elasticities of price with respect to square footage are in the range of 0.06 (for one-year lag) to 0.11 (for 3- or 5-year lags). The elasticity of price with respect to income is much higher, ranging between 0.35 (for one-year lag) to 0.43 (for 3- or 5-year lags). When both lagged square footage and lagged tract income are included in the same hedonic regression, the square footage elasticities are larger, in the range of 0.08 to 0.16, while the income elasticities are modestly higher. 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: 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 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. For the “group fixed effects” in column (1), we find no significant relationship between noise and the number of bedrooms, noise and the number of bathrooms, and noise and the interior square footage; lot size and noise have a significant positive relationship. In the tract fixed effects results in column (2), none of the characteristics have a significant relationship with noise. Overall, these results provide strong evidence that the characteristics of houses sold in noisy and less noisy areas, before the announcement, were not different. In Panel 2, since the actual closing announcement occurred in 1985, we consider a “fake” announcement in 1982, long before the actual announcement. We find the treatment effect to be negative and significant, implying expectations of further decreases in house prices due to increasing air traffic at the old airport. In Panel 3, we use a propensity score approach to match non-noisy properties (i.e., those with “fake” noise) with noisy properties based on similarities in property characteristics. Then we estimate a set of difference in differences regressions based on the 1985 announcement (column 1) and the 1995 closing event (column 2). In both cases, the treatment effect on the “fake” noise variable is statistically insignificant. 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)



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 3.

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 4.