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Changing Noise Levels and Housing Prices near the Atlanta Airport

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Abstract

Using hedonic models, we analyze the effects of proximity and noise on housing prices in neighborhoods near Hartsfield-Jackson Atlanta International Airport during 1995-2002. Proximity to the airport is related positively to housing prices. We address complications caused by changes over time in the levels and geographic distribution of noise and by the fact that noise contours are measured infrequently. A general decline in noise boosted housing prices during 1995-2002. After accounting for proximity, house characteristics, and demographic variables, houses in noisier areas sold for less than houses subjected to less noise. Also, the noise discount is larger during 2000-2002 than 1995-1999.

JEL Codes: Q53, Q51, R31, L93
Keywords: noise, airports, housing prices, hedonic pricing, proximity

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Introduction

Airports generate both undesirable impacts, such as noise, and desirable impacts, such as employment opportunities and transportation services. In assessing the effects of airports on housing prices, issues related to geography come to the fore. In this paper, we estimate the impact of airport-related noise on housing prices during 1995-2002 in neighborhoods near Hartsfield-Jackson Atlanta International Airport. We address complications that arise because the airport noise contours are produced infrequently and change over time. We also explore how proximity to an airport affects housing prices.

Our analysis uses a hedonic pricing model. Hedonic models have been used for many years in housing price studies, with numerous studies producing estimates of the values of amenities as well as disamenities on housing prices.[1] Despite several hedonic airport noise studies, few recent studies have examined noise effects of U.S. airports on housing prices and no known studies have produced estimates of the changing impact over time of given noise levels at a specific airport.[2]

Coinciding with our focus on noise and housing prices is the simultaneous consideration of proximity and housing prices. Tomkins et al. (1998) and McMillen (2004a) have found that proximity to airports in Manchester, England, and Chicago, respectively, had a positive effect on housing prices. Access to airport-related jobs and

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[1] For example, see Greenbaum et al. (2005) – crime, Kiel and Boyle (2001) and Anstine (2003) – environmental disamenities, and Benson et al. (1998) – environmental amenities.

[2] The hedonic price method, which uses revealed preference, is the most common approach for assessing the cost of noise. This cost has been examined to a very limited extent via three other methods—artificial neural networks, contingent valuation, and happiness surveys. See Collins and Evans (1994), Feitelson et al. (1996), and van Praag and Baarsma (2005), respectively. The use of artificial neural networks also relies on revealed preference. The other methods rely on subjective, survey-based information.

air transportation services can become capitalized into the value of a house. Moreover, ignoring the value of accessibility could bias the estimates of the impact of noise.

For comparability purposes, the results of two recent studies are especially relevant. McMillen (2004a) found that residential property values for houses subjected to a noise level of 65 or more decibels near Chicago's O'Hare Airport were about nine percent lower than otherwise similar homes.[3] Similarly, Espey and Lopez (2000) estimated a $2400 difference, slightly more than two percent, in the price of a house in Reno-Sparks, Nevada, in areas with a noise level of at least 65 decibels.

Two prior studies have examined the effect of noise at the Atlanta airport on property values. O'Byrne et al. (1985) examined the prices of properties near the Atlanta airport for 1970-72 and 1979-80. Noise negatively affected price in both sets of regressions. Moreover, despite using prices based on individual house sales in one period and owner-appraised Census block aggregates in the other period, their results revealed similar estimates of the noise discount for the two periods. The other study, Lipscomb (2003), examined the sales of 105 single family dwellings in the small city of College Park that occurred from January 1997 to February 2000. In contrast to O'Byrne et al. (1985), Lipscomb (2003) found that airport noise did not have a statistically significant effect on housing prices.

Our research updates and extends O'Byrne et al. (1985) and Lipscomb (2003). A noteworthy extension is that it produces results on how the impact of noise on housing prices has changed over time at a specific airport. In a survey of airport-related noise estimates and housing prices, Nelson (1980) concluded that the impact of noise was

[3] Nonetheless, because the noise associated with aircraft is diminishing over time, McMillen (2004a) estimated that prices for houses near O'Hare would rise if an additional runway were built.

relatively stable across studies; however, a review by Schipper et al. (1998) of 19 studies found much variation among the estimates produced by the studies. Much of this variation could be explained by differences across studies in terms of either the characteristics of the sample population (e.g., mean house price) or the study (e.g., time period, country, and specification). In a recent meta-analysis using 33 estimates for 23 airports in the United States and Canada, Nelson (2004) concluded that variability in estimated noise discounts was related to the country in which the airport was located and to the specification of the hedonic model.

In contrast to prior studies, our study uses price data from one source over a moderately long time period, eight years, to explore how the price impact of noise on houses near the Atlanta airport has changed over time. Such an approach is preferable to making inferences based on studies for various airports at different points in time. Our analysis, however, is complicated by the fact that over time a particular house is subjected to different noise levels that are not measured precisely. Noise regulations, quieter aircraft, and soundproofing programs have likely affected the quantity and impact of airport noise on housing prices over time.

Data and Model

The standard categories of explanatory variables used in studies of housing prices are the structural features of the housing units, location characteristics, and attributes of the social and natural environment. To estimate the impact of specific determinants, we combined data from various sources. The data consist of noise contour maps for the neighborhoods near the airport, demographic data on a block-group basis for median household income and the percent of housing occupied by blacks, as well as data for single family house sales, including sales prices, location, and housing characteristics.

Noise contour files for 1995 and 2003, in a format compatible with ArcView Geographic Information Systems (GIS) software, were provided by the City of Atlanta Department of Aviation.[4] The noise contour maps are based on a standard measure of noise used by the Federal Aviation Administration and other federal agencies. This measure, the yearly day-night sound level (DNL), is measured in decibels. Because an increase of 10 decibels is equivalent to a ten-fold increase in sound, a ten-unit increase in the DNL can be viewed similarly.

Nelson (2004) notes that normal background noise levels in urban areas are approximately 50-60 decibels during daytime hours and 40 decibels during nighttime. A DNL of 65 decibels is the Federal Aviation Administration's lower limit for defining a significant noise impact on people.[5] At 65 decibels and above, individuals experience the disruption of normal activities, such as speaking, listening, learning, and sleeping. A DNL of 75 decibels or more is viewed as incompatible with single family housing.[6]

In contrast to many studies that identify their "noisy" area by one noise contour (i.e., 65 or more decibels), the current analysis uses two noise contours, one for 65

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[4] ArcView GIS software enables the user to read noise contour maps and match the corresponding noise data with other geo-coded data corresponding to individual properties. Nelson (2004) refers to GIS studies as the "next generation of hedonic studies." For an overview of applying GIS to economic issues, see Bateman et al. (2002).

[5] See *U.S. Federal Interagency Committee on Noise* (1992a,b) for this standard. This standard, however, is somewhat controversial. Sobotta et al. (2007) note that the Environmental Protection Agency and the World Health Organization consider 65 DNL unacceptably high. Research on noise suggests that roughly 12 percent of people subjected to a DNL of 65 decibels report that they are "highly annoyed" by transportation noise. Meanwhile, about 3 percent are highly annoyed when subjected to a DNL of 55 decibels and nearly 40 percent are highly annoyed at a DNL of 75 decibels. See *Federal Register* (2000).

[6] Nelson (2004) notes that since 1979 federal agencies have regarded land subjected to DNLs ranging from 65 to 74 decibels as "normally" incompatible with residential use, while land exposed to a DNL of less than 65 decibels is regarded as "normally" compatible with residential land use.

decibels (i.e., 65 to less than 70 decibels) and one for 70 decibels (i.e., 70 to less than 75 decibels). Single family dwelling sale price data for the years 1995 through 2002 have been purchased from First American Real Estate Services for the Atlanta neighborhoods that fall in the 65 DNL and 70 DNL boundaries, as well as within a half mile outside of the 65 DNL boundary, which is termed the "buffer zone."[7] [8] Relative to the buffer zone, it is expected that, all else equal, houses subjected to more noise will sell for lower prices.

One complication for the current analysis is that the noise levels for a specific house have likely changed over time and precise measurement of these changes is lacking. This issue is addressed in more detail later; at this point, we discuss one reason for changing noise levels and our response to this complication.

Prior to 1968, aircraft noise was not regulated on a national basis in the United States. Following Congressional authorization, the Federal Aviation Administration promulgated standards requiring that the best available noise reduction technology be used in new designs of civil subsonic turbojet aircraft. Aircraft satisfying this standard were categorized as Stage 2 aircraft, while those not meeting this standard were classified as Stage 1 aircraft. In 1977, the Federal Aviation Administration adopted more stringent noise standards that applied to all newly manufactured aircraft. Aircraft meeting the new standards, which only apply to commercial subsonic jet aircraft over 75,000 pounds, were classified as Stage 3 aircraft. Following passage of the Airport Noise and Capacity Act in 1990, all commercial jets operating in the United States were required to be Stage 3

[7] We eliminated 28 sales in the 75 decibel noise contour from the sample.
[8] We chose the 0.5 mile buffer zone rather than the entire metropolitan area for three reasons. First, other airport noise studies have handled analogous problems similarly. Second, we wanted to examine the impact of additional noise relative to some base that exhibits some noise. Third, other parts of Atlanta may face different housing price determinants than the area surrounding the airport.

compliant by December 31, 1999. Thus, one implication to be drawn from phasing-in the Stage 3 requirement is that noise levels throughout the sample area should be lower at the end of our time period relative to the beginning. We use a dummy variable to separate the phase-in period that lasts through 1999 from the latter period, 2000-2002.[9]

The geographic area that is examined and the relevant noise contours for 1995 are shown in Figures 1 and 2. The airport lies ten miles south of downtown Atlanta. The area under consideration covers parts of Atlanta and five other cities—College Park, Conley, East Point, Forest Park, and Hapeville. This sample consists of 2,370 house sales from 1995 through 2002.

Nominal housing sale prices are deflated by the National Association of Realtors median housing price index for Atlanta, with 1995 median sales price for Atlanta as the base year. We refer to these prices as adjusted prices. Between 1995 and 2002 this housing price index increased 50 percent, substantially larger than the 20 percent increase in the consumer price index. In addition to the sales price, housing characteristics such as the numbers of stories, bedrooms, baths, fireplaces, lot size, and the age of the dwelling were contained in the purchased dataset. Table 1 lists the variables used in our analysis and how these variables were measured, while Table 2 contains summary information of these data.[10] Each of the housing characteristics variables, with the exception of the age of the dwelling, is expected to be related positively to housing prices. An increase in the age of a house, holding all other things constant, should tend to reduce its price.

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[9] The re-drawing of the noise contours causes some houses to switch from one noise area to another one. This issue is addressed later.

[10] Following Pennington et al. (1990) and Espey and Lopez (2000), dummy variables are used for measuring selected structural housing characteristics, such as the numbers of bedrooms, bathrooms, and fireplaces.

The demographic data are from the Bureau of the Census. Because there are no annual data for neighborhood characteristics, we use 2000 Census data for the sales in all sample years.[11] Specifically, the block group data came from the 2000 Summary Tape File 3 – Sample data. With respect to the neighborhood characteristics, we examine two variables—median household income and the racial composition of the neighborhood. We expect the sign on the income coefficient to be positive due to the neighborhood effects. In other words, houses in neighborhoods where residents have higher incomes should have higher prices. Our expectation concerning the relationship between the percentage of housing occupied by blacks and housing prices is based on O'Byrne et al. (1985), who found a negative relationship.[12] However, possible changes in racial attitudes as well as differences in the composition of the neighborhoods examined here versus those examined by O'Byrne et al. raise some doubts about this expectation.

In addition to noise and neighborhood characteristics, the location of a house is likely to affect its price via some other characteristics. Whether the house is located in Atlanta, College Park, Conley, East Point, Forest Park, or Hapeville is potentially important. The benefits and costs of publicly-provided services as well as other features of cities can differ and affect housing prices. We have no expectation as to how housing prices in specific cities are likely to be affected.

Finally, ArcView was used to calculate the distance between each property address and the airport. After accounting for airport noise, the authors expect that less distance from the airport should result in higher housing prices, due to more convenient

[11] We also ran regressions in which they replaced 2000 Census data with 1990 Census data. These results do not differ materially from their reported results.
[12] Greenbaum et al. (2005) found a positive relationship between housing prices and the percentage of white population for neighborhoods in Columbus, Ohio.

access to jobs at the airport and air transportation service.[13] [14] Ignoring the value of accessibility to the airport could bias the estimated noise effect downward (i.e., to showing a lessened effect). Thus, the model is a hedonic housing price model, with the individual housing characteristics, noise exposure, neighborhood characteristics, the city in which the house is located, and distance to the airport as the explanatory variables. For some regressions, we also included variables to capture the timing of the sale, such as the year or the month (or both) in which the sale occurred.

We estimated numerous hedonic housing price models.[15] Three functional forms—a double log form, a semi-log form, and a linear form—were examined. Because of the similarity of the results and to reduce the size of the tables, we have chosen to report only the results of the semi-log and linear functional forms. The change in the geographic distribution of noise that occurred between 1995 and 2003 complicates our attempt to precisely identify the quantitative relationship between noise and housing prices. The first set of results assumes that houses were subjected to noise based on the 1995 noise contours from 1995 through 2002. The second set of results is based on a reduced sample constructed by using information from both the 1995 and 2003 noise contours.

Results – Base Model Using 1995 Noise Contours

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[13] Proximity to an airport may have positive (due to accessibility) as well as negative (due to noise) effects on property values. Tomkins et al. (1998) found that the benefits of easy access to the airport outweighed the costs of living near the airport in Manchester, England. In contrast, Espey and Lopez (2000) found proximity to an airport in Reno, Nevada to be a disamenity.

[14] Numerous studies have related property values to the distance from rail stations. Bowes and Ihlanfeldt (2001, p. 3) conclude that "the majority do find that rail stations have a positive (but relatively modest) impact on nearby property values." Bowes and Ihlanfeldt examine four factors related to proximity that might affect property values. The positive factors are the transportation access advantage provided by rail stations and the increased retail activity stemming from rail stations. The negative factors are crime and environmental disamenities, such as noise, pollution, and the unsightliness of rail stations. In their study of Atlanta's rail system, all four factors affected property values.

[15] An alternative approach using spatial econometrics would incorporate the impacts of the spatial locations of other houses in determining the price of a specific house. See Cohen and Coughlin (forthcoming).

Table 3 contains the results of models using the noise contours for 1995. The estimated models explain 45 percent of the variation in housing prices in the semi-log functional form and 40 percent for the linear form. Nearly every individual variable performed as expected.

Variables measuring the structural characteristics of houses exhibited the expected impact on housing prices and, virtually without exception, were statistically significant, often at the 1 percent level. For example, the dummy variables differentiating houses based on the number of bedrooms, *Beds3d*, *Beds4d*, and *Beds5d*, were all related positively to housing prices and, except for *Beds3d* in the linear form, were statistically significant. Moreover, the size of the estimated coefficients increases as the number of bedrooms increases. The results for the number of bathrooms are similar to the results for the number of bedrooms. Both dummy variables differentiating houses based on the number of bathrooms, *Baths2d* and *Baths3d*, were related positively to housing prices, increased in size with the number of bathrooms, and were statistically significant. The dummy variable differentiating houses with two or more fireplaces from other houses, *Fire2d*, was related positively to housing prices and was statistically significant. The dummy variable differentiating houses with two or more stories from other houses, *Storiesd*, was also found to be a positive, statistically significant determinant of housing prices. The variable measuring the age of the house, *Age*, was related negatively to housing prices, but this variable was not statistically significant for the linear specification. This lack of significance of *Age* indicates that newer houses did not tend to sell for significantly higher prices than older houses. Finally, indicating that larger lots were associated with higher housing prices, the variable measuring lot size, *Acres*, was related positively to housing prices and was statistically significant.

Turning to the neighborhood characteristics, the percentage of houses in a neighborhood occupied by blacks, *BlackPerc*, was related negatively to housing prices and was statistically significant. Numerous regressions were run that included median household income in the neighborhood in which a house was sold. This variable was not included in the reported results because it was not found to be statistically significant.

The dummy variables differentiating the cities in this housing sample provided explanatory power. Relative to Atlanta, ceteris paribus, houses in College Park (*City2d*) and East Point (*City4d*) tended to sell for higher prices, while houses in Conley (*City3d*) and Forest Park (*City5d*) tended to sell for lower prices. Houses in Hapeville (*City6d*) tended to sell for prices similar to those in Atlanta.[16]

The remaining results concern the variables related to the airport—distance and noise.[17] Some weak evidence is found indicating that the distance from a house to the airport affects the price of the house. The variable measuring that distance, *Distance*, was related negatively to housing prices; however, a statistically significant relationship was found only for the linear specification. These results are consistent with findings by Lipscomb (2003) that houses closer to the Atlanta airport tended to sell for higher prices.[18] Our results are also consistent with findings by Tomkins et al. (1998) that proximity to the airport in Manchester, England, and by McMillen (2004a) that proximity

[16] Given our focus on the impacts of noise and proximity on housing prices, no speculation on the reasons for the results involving specific cities is provided.
[17] Regardless of the sample size, the distance and noise measures show little correlation.
[18] Based on conventional significance levels, however, Lipscomb (2003) did not find a statistically significant relationship between distance to the airport and housing prices.

to Chicago's O'Hare Airport were amenities, but are inconsistent with a finding by Espey and Lopez (2000) that proximity to the airport in Reno, Nevada, was a disamenity.

Concerning to airport noise, the results are mixed. Regardless of functional form, airport noise is related negatively to housing prices, but the relationship is statistically significant only for the 65 decibel noise contour, *Noise65d*_95, and housing prices. The relationship between the variable for the 70 decibel noise contour, *Noise70d_95*, and housing prices is not statistically significant. Consistent with our expectation, the attempt to differentiate the phase-in period of Stage 3 aircraft from full compliance appears to succeed. *NoiseRegd* is a positive, statistically significant determinant of *AdjPrice*. One can view this variable as capturing a broad-based reduction in noise levels between 1995-1999 and 2000-2002. Our interpretation, which can be questioned, suggests that this regulation affected all housing prices in the sample area, regardless of the initial noise levels. Additional evidence on this issue is provided later.

Potential Biases Stemming from Changing Noise Contours

One question that deserves scrutiny is whether there are potential biases from the use of the 1995 contours for the entire period. A comparison of the 1995 contours with contours estimated for 2003 suggests that the noise contours have changed between 1995 and 2003. Figure 3 shows how the 65 decibel noise contour has changed between 1995 and 2003. Generally speaking, the 65 decibel noise contour has shifted closer to the ends of the runways. This change and a similar change for the 70 decibel noise contour have resulted from a combination of technological changes, regulatory policy, and airport authority efforts to reduce the effects of noise.[19]

The preceding discussion indicates that both the 70 decibel and 65 decibel noise contours have collapsed toward the airport over time so that some houses became subject to less noise. Meanwhile, the buffer zone becomes a relatively larger share of the area under consideration and it too has become subject to less noise. Thus, on average, the houses in each of these areas should tend to increase in value. Our results for *NoiseRegd* are consistent with this expectation. Two caveats, however, should be highlighted. First, some factor other than declining noise levels might be responsible, at least partially, for this result. In other words, some variable, not included in this model, could have changed between 1995-1999 and 2000-2002 that made houses in the sample relatively more attractive than houses overall in the Atlanta area. Second, the use of *NoiseRegd* does not preclude the possibility that the inaccurate measurement associated with the changing noise contours could bias our estimates with respect to specific noise contours.

Our study uses the 2003 contours to reduce the dataset to address the issue of changing noise levels. We restrict the sample to only those houses that remained in the same contour throughout the sample period. In other words, the resulting sample consists of houses in the 70 decibel contour using both the 1995 and 2003 noise contours, houses in the 65 decibel contour for both noise contours, and houses in the buffer zone for both noise contours. The dummy variables identifying houses in the 65 and 70 decibel noise contours using 1995 and 2003 measures are *Noise65d_9503* and *Noise70d_9503*,

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[19] Additional information on this topic can be found on the airport's website: www.atlanta-airport.com. After reaching the site, navigate through "Airport Information," "Environmental," and then "Noise and Operations Monitoring System" (NOMS).

respectively. Houses classified as switching noise areas between 1995 and 2003 were deleted.[20]

As a result, the sample size decreased from 2370 to 1643. In addition, as indicated in Table 4, the distribution of houses across the three noise areas changed. The location of houses in this sample is shown in Figure 4. The percentage of houses in the buffer zone increased by nearly 19 percentage points, while the percentage of houses in the 65 and 70 decibel noise contours declined by roughly 12 and 6 percentage points, respectively. Some minor changes can also be observed in the means of the variables. Not surprisingly, with the relative decline of the houses in the 65 and 70 noise contours, the mean of the adjusted sales price rose as did the distance from the airport. Neighborhood characteristics also changed. The average percentage of houses in the neighborhood occupied by blacks fell.

What can be said about potential bias using this sample? Using this reduced sample, it is clear that houses in the 70 decibel and 65 decibel noise contours are subject to roughly the same noise levels throughout the period. (More precisely, the houses in the 70 decibel noise contour are subject to at least 70 decibels of noise throughout the period, with some houses subjected to slightly less noise at the end of the period than at the beginning.) Meanwhile, houses in the buffer zone are likely to be subject to less noise over time. Because the houses in the buffer zone are expected to be affected only minimally by noise, an argument can be made that any reduction in noise for these houses

[20] McMillen (2004b) follows another approach to analyze whether homes have risen faster in neighborhoods where noise exposure has changed over time. He assigns dummy variables to properties that switched sides of the 65 decibel noise contour over time, and for the most part finds that on average the houses that switch sides of the noise contour over time do not significantly appreciate. We did run regressions using the entire sample and identified houses that were reclassified into a different noise contour using the 1995 and 2003 noise contours. The results of these regressions, available upon request, indicate no statistical significance for the reclassified houses and do not differ from our reported results.

is likely to have a negligible effect on their price, especially given the inclusion of *NoiseRegd*. This is especially pertinent due to the construction of this sample. Thus, relative to the buffer zone, the noise discount estimates, to the extent that any bias exists, should be biased high.

Results – Base Model Using the 1995 and 2003 Noise Contours

Table 5 contains the results using the sample restricted to housing sales that occur in the same noise contour using both the 1995 and 2003 noise contours. Given the focus of this paper, we focus our discussion on the results for the variables related to the airport.[21]

We begin by discussing the results in Table 5 that are based on the model using the same variables as in Table 3. The results for *NoiseRegd* are similar regardless of the sample and the measurement of the noise levels. In fact, the parameter estimates for this variable are slightly larger when the smaller sample is used. Thus, there appears to be a consistent positive effect from the general noise reduction in the area near the airport.

The results also indicate that the distance from a house to the airport affects the price of a house. The variable measuring distance, *Distance*, is related negatively to housing prices and is statistically significant. Comparing the parameter estimates, one sees that in Table 5 the marginal value of proximity is much larger than in Table 3.

Earlier we noted that the exclusion of the distance variable could bias the noise results. A comparison of the results of Table 5 with a model that excludes distance confirms this possibility. Excluding proximity tends to shrink the estimated impact of noise on housing prices. Based on the model in Table 5, the parameter estimates for the 65 decibel noise contour for the semi-log and linear functional forms when proximity is

[21] The results in Tables 3 and 5 for the variables not directly related to the Atlanta airport are very similar.

excluded (included) are: -0.024 (-0.030) and -3,451 (-3,962). The parameter estimates for the 70 decibel noise contour are: -0.042 (-0.063) and -7,909 (-9,622).

Turning to the noise variables, the parameter estimates for the noise discounts are larger in Table 5 than in Table 3. Contrary to the results in Table 3, the results in Table 5 for the 70 decibel noise contour are statistically significant. Moreover, the relative magnitudes of the parameter estimates for the 65 and 70 decibel noise contours are consistent with expectations (i.e., the noise discount for houses in the 70 decibel noise contour is larger than for houses in the 65 decibel noise contour).

Recall that a case can be made that the estimates in Table 5 are biased high. Thus, these estimates provide an upper bound on the noise discount. The coefficient for the 65 decibel noise contour in the semi-log specification has a value of -0.030, which implies that after accounting for other physical and neighborhood characteristics, houses in this noise contour sold for about 3.0 percent less on average than houses in the buffer zone.[22] Meanwhile, the coefficient for the 70 decibel noise contour suggests a noise discount of 6.1 percent. Thus, the noise discount for houses in the 70 decibel noise contour is slightly more than double that of houses in the 65 decibel noise contour.

To make these results more directly comparable to existing studies, we calculated the weighted sum of the two noise discounts. In contrast to our finding of 3.3 percent, Espey and Lopez (2000) estimated a noise discount of 2.4 percent for houses subjected to noise levels of 65 or more decibels for the Reno airport, while McMillen (2004a) estimated a 9 percent noise discount for houses subjected to 65 or more decibels for Chicago's O'Hare Airport. In addition to examining different geographic areas, different

[22] The estimated coefficient for the noise contours using the semi-log functional form is nearly equal to the noise discount. In percentage terms, the noise discount equals $(e^{\beta} - 1) \times 100$, where e is the base of the natural exponential function and β is the parameter relating noise to housing price.

time periods of other studies may account for some of these differences between their findings and ours.

Finally, for the linear specification, the results in Table 5 indicate noise discounts for the 65 and 70 decibel noise contours of $3,962 and $9,622, respectively. With the average adjusted price of a home in the buffer zone equal to $74,414, the sales prices of homes in the 65 and 70 decibel noise contour bands are roughly 5.3 and 12.9 percent, respectively, lower than in the buffer zone.[23] The weighted sum of these noise discounts is 6.1 percent, which is nearly double our finding for the semi-log specification.

Results – Controlling for the Time of Sale

One concern about the analysis presented so far is that we might not have controlled adequately for the time of sale. Our analysis has included some factors that control for the time of sale. First, we adjust sales prices in a given year by a yearly median housing price index. This should control for year-to-year changes in housing prices in Atlanta. Second, our dummy variable for noise regulation, *NoiseRegd*, distinguishes between sales during 1995-1999 versus 2000-2002. A reasonable question is whether our results hold up to other attempts to control for the time of sale.

To control for the time of sale, we added year dummies separately, monthly dummies separately, year and monthly dummies together, and dummies for each quarter/year in our sample. In reviewing the results of numerous regressions, the inclusion of year dummies separately yielded results as good as any of our other attempts to control for time of sale. We did not find any seasonal pattern. Results using the year dummies are listed in the right-hand columns in Table 5. We use 1995 as the base year

[23] Consistent with a general finding by Schipper et al. (1998), the estimated impact of noise on housing prices tends to be larger for the linear specification relative to semi-log specification.

for this set of dummies, so the estimate for the impact on housing prices for a specific year is relative to 1995.

Generally speaking, the inclusion of the year dummies had little effect. The overall explanatory power of the models was unchanged and the parameter estimates and their statistical significance changed only minimally. Turning to the year dummies, a number of observations can be made. First, because of multicollinearity, the inclusion of the year dummies precluded the continued inclusion of *NoiseRegd*. Second, the parameter estimates for the year dummies were always positive and the relationship between the year dummies and the adjusted housing prices was generally statistically significant. Third, the parameter estimates for 2000, 2001, and 2002 are very similar and much larger than the estimates for the prior years. Statistically, this is a major reason why the results for the models using *NoiseRegd* are so similar to those using the year dummies.

These results, which are admittedly suggestive and far from conclusive, support our argument that *NoiseRegd* is likely capturing the impact of noise reduction. Note that by using adjusted housing price as the dependent variable, we are estimating the change in housing prices in the area near the airport relative to housing prices throughout the metropolitan area. At this point, our argument about noise remains tentative as we cannot rule out that some factor other than noise is driving our result.

Results - Using Nominal Prices

In addition to concerns about not adequately controlling for the time of sale, a referee asked about the effects of replacing adjusted housing prices with nominal housing prices. Table 6 contains the results of one set of our regressions that is representative of our complete set of regressions.

These regressions produced an increase in overall explanatory power. For the semi-log functional form including year dummies, R^2 increased from 0.48 to 0.58, while for the linear functional form, R^2 increased from 0.42 to 0.49. Not surprisingly, due to the upward trend in Atlanta housing prices over 1995-2002, the parameter estimates for the year dummies increased throughout the period. A similar comment applies to the magnitudes of the estimates for the other variables using the linear functional form.

Results – Did the Noise Discount Change Differentially?

So far in this analysis, the results suggest that reduced noise levels between 1995-1999 and 2000-2002 had a positive impact on housing prices for the entire sample area near the Atlanta airport. The next topic explored is the possibility that the noise discount might have changed differentially depending on the noise contour in which a house was located.[24]

There are many reasons why the actual noise discount might change differentially across noise contours. Moreover, it is not clear whether this noise discount is more likely to increase or decrease over time. With increasing incomes and with noise being a disamenity, then the noise discount should tend to increase over time. It is possible that houses subjected to more noise would be sold at increasing discounts.

Another reason, suggested by a referee, involves the interplay between noise regulations and consumer expectations. We noted earlier that the passage of the Airport Noise and Capacity Act in 1990 led to the expectation that noise levels throughout our

[24] The authors also examined time trends for the other independent variables. Their results revealed no linear time trend between these variables and housing sales prices.

sample area should be lower at the end of the sample time period relative to the beginning. It is possible that homebuyers and homeowners had an overly optimistic view of the magnitude of the likely noise reduction at the beginning of our sample period. As the uncertainly about noise levels is reduced and actual noise levels turn out to be higher than initially expected, then the estimated noise discount would be larger for the period at the end of our time period relative to the beginning.

On the other hand, airport authorities were pursuing policies during the time period under consideration to reduce the effects of noise.[25] For example, houses within the noise contours were soundproofed. Such efforts should make the purchase of these houses more desirable and, consequently, reduce the noise discount.

Table 7 contains the results of adding two variables, *Noise65dDif* and *Noise70dDif*, which allow the impact of noise in the 65 and 70 decibel noise contours to change between 1995-1999 and 2000-2002. Adding these variables only affected the results concerning noise. The overall explanatory power of the models remained unchanged and the other individual variables were affected only minimally.

One finding is that the parameter estimates for *NoiseRegd* in Table 7 are larger than the comparable estimates in Tables 3 and 5. For example, the comparable parameter estimates for the semi-log functional form are: 0.189 (Table 7), 0.155 (Table 5), and 0.136 (Table 3). The comparable parameter estimates for the linear functional form are; 14,929 (Table 7), 11,624 (Table 5), 10,590 (Table 3). Regardless of the specification,

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[25] According to the authorities at the Atlanta Airport (http://www.atlanta-airport.com/sublevels/airport_info/noise.htm): "The DOA's Noise Mitigation Program's purpose is to be proactive in addressing eligible noise-impacted properties inside the approved noise contours. This program provides assistance to the communities surrounding HJAIA by continuing to reduce noise-sensitive uses inside the 70 DNL through acquisition/relocation, and complete acoustical treatment for the remaining noise-sensitive uses inside the 65 DNL, thereby enhancing their living conditions."

housing prices are affected positively by roughly 20 percent. It is possible that the estimates in Tables 3 and 5 are biased because these models did not allow for differential changes across noise contours. In Table 7 the estimate for *NoiseRegd* might no longer be capturing some of the increase in the noise discount for the 65 and 70 decibel noise contours.

Turning to the noise-related results associated with the possibility of differential changes across noise contours, our evidence suggests that the measured noise discount within the 65 decibel noise contour has tended to become larger. Regardless of the functional form *Noise65dDif* is a negative, statistically significant determinant of housing prices. The results for the noise discount within the 70 decibel contour have also tended to become larger; however, a statistically significant relationship between *Noise70dDif* and housing prices was found only for the linear specification.

The results in Table 7 indicate no statistically significant noise discount for 1995-1999. Such a finding is consistent with Lipscomb (2003), whose sample covered January 1997 to February 2000. Nonetheless, for 2000-2002 tests reveal that *Noise65d_9503* and *Noise65dDif* are always jointly significant. A similar comment can be made concerning the 70 decibel noise contour. For 2000-2002 the estimates for the models with *NoiseRegd* and without the year dummies indicate that the noise discount for the 65 decibel noise contour was 7.5 percent for the semi-log specification and $8,612 or 10.6 percent for the linear specification. The comparable estimates for the 70 decibel noise contour are 12.3 percent and $14,330 or 17.7 percent.[26]

[26] As can be seen in Table 7, the estimates for the noise discounts are virtually the same for the models with *NoiseRegd* relative to the models with year dummies.

Of course, the preceding numbers are not the end of the story because of the impact of the variable, *NoiseRegd*, that attempts to differentiate between the phase-in period of noise regulation from 2000-2002.[27] When one includes this variable, then housing prices in both noise contours (as well as the buffer zone) were affected positively. The estimates in Table 7 indicate the overall positive impact of noise changes for the 65 decibel contour was 11.7 percent for the semi-log specification and $6,318 or 7.8 percent for the linear specification. The comparable estimates for the 70 decibel noise contour are 6.0 percent and $600 or 0.7 percent.

Conclusion

We produce results on two dimensions of housing prices near the Atlanta airport. In the process of generating specific results, we address complications caused by changes over time in the levels and geographic distribution of noise and by the fact that noise levels are measured only at the beginning and after the end of the sample period.

Consistent with most studies, including Lipscomb (2003), proximity to the airport is related positively to housing prices. Moreover, when this variable is excluded, the estimated impact of noise on housing prices is much less in absolute value than when this variable is included. Thus, ignoring the value of accessibility likely biases the estimated noise effect to showing a lessened impact.

Our second, more extensive set of results involves the relationship between noise and housing prices. This analysis is complicated by changing, generally declining, noise levels that are measured only at the beginning and end of the sample period. Our

[27] For those remaining highly skeptical of what *NoiseRegd* is capturing, the story does end before going any further.

preferred sample includes houses that are located in the same noise contour regardless of when the noise contours are constructed.

We find evidence indicating that the prices of houses near the Atlanta airport were affected positively by declining noise levels. The magnitude of the resulting impact on housing prices, roughly 20 percent, is substantial.

Turning to the issue of whether houses in noisier areas sell for less than those subject to less noise, previous research involving the Atlanta airport is mixed. We find, consistent with O'Byrne et al. (1985), that airport-related noise having a "significant noise impact on people" is associated with lower housing prices.[28] The point estimates of the noise discount are sensitive to both the functional form and the noise contours used to classify houses. Generally speaking, the linear specification yields the largest estimate of the noise discount. Using our preferred sample, we estimate the noise discount for the 65 decibel noise contour for 2000-2002 to be 7.5 percent for the semi-log specification and $8,612 or 10.6 percent for the linear specification. The comparable estimates for the 70 decibel noise contour are 12.3 percent and $14,330 or 17.7 percent.

A novel feature of our study was the attempt to identify whether and how this noise discount has changed over time. Comparing 1995-1999 with 2000-2002, we find that the noise discount is relatively larger during the latter period. This result warrants additional scrutiny in other settings.

Finally, combining the impact of the general reduction in noise with their noise discount estimates, we find that between the periods 1995-1999 and 2000-2002 housing prices in areas subjected to noise levels of 65 or more decibels have increased. Our

[28] Nonetheless, as noted in the body of the paper, these results are consistent with those of Lipscomb (2003).

estimates indicate the overall impact of noise changes for the 65 decibel contour was 11.7 percent for the semi-log specification and $6,318 or 7.8 percent for the linear specification. The comparable estimates for the 70 decibel contour are 6.0 percent and $600 or 0.7 percent.

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Table 1	
Variables in Hedonic Regressions	
Name	Definition
NomPrice	Nominal house sale price.
AdjPrice	House sale price deflated by median housing price index for Atlanta.
Noise65d_95	Dummy variable equal to one for houses within the 65 decibel day-night sound level 1995 noise contour; zero otherwise.
Noise70d_95	Dummy variable equal to one for houses within the 70 decibel day-night sound level 1995 noise contour; zero otherwise.
Beds3d	Dummy variable equal to one for houses with three bedrooms; zero otherwise.
Beds4d	Dummy variable equal to one for houses with four bedrooms; zero otherwise.
Beds5d	Dummy variable equal to one for houses with five or more bedrooms; zero otherwise.
Baths2d	Dummy variable equal to one for houses with two bathrooms; zero otherwise.
Baths3d	Dummy variable equal to one for houses with three or more bathrooms; zero otherwise.
Fire2d	Dummy variable equal to one for house with two or more fireplaces; zero otherwise.
Storiesd	Dummy variable equal to one for houses with more than one story; zero otherwise.
Age	Age of house in years at the time of its sale.
Acres	Lot size in acres.
Distance	Distance in miles from house to airport.
BlackPerc	Percentage of homes in the neighborhood in which a house was sold occupied by blacks; 2000 Census data is used for sales in all years.
City#d	Series of dummy variables: *City2d* for College Park, *City3d* for Conley, *City4d* for East Point, *City5d* for Forest Park, and *City6d* for Hapeville, using Atlanta as the base city.
Noise65d_9503	Dummy variable equal to one for houses with the 65 decibel day-night sound level noise contour for both 1995 and 2003; zero otherwise.
Noise70d_9503	Dummy variable equal to one for houses with the 70 decibel day-night sound level noise contour for both 1995 and 2003; zero otherwise.
NoiseRegd	Dummy variable equal to 1 if houses sold during 2000-2002; zero otherwise.
Yeard	Series of dummy variables for the year of the sale: 1996, 1997, 1998, 1999, 2000, 2001, and 2002, using 1995 as the base year.
Noise65dDif	Dummy variable equal to 1 if houses sold during 2000-2002 within the 65 decibel noise contour; zero otherwise.
Noise70dDif	Dummy variable equal to 1 if houses sold during 2000-2002 within the 70 decibel noise contour; zero otherwise.

Table 2: Summary Statistics, Full Sample -- 2370 Observations		
	Count	**Frequency**
House Sales in the buffer zone -- 1995 contours	1008	42.53
House Sales in 65 db zone – 1995 contours	1113	46.96
House Sales in 70 db zone – 1995 contours	249	10.51
House Sales in Atlanta	111	4.68
House Sales in College Park	490	20.68
House Sales in Conley	417	17.59
House Sales in East Point	366	15.44
House Sales in Forest Park	833	35.15
House Sales in Hapeville	153	6.46
1 story	2143	90.42
2 or more stories	216	9.11
3 bedrooms	1589	67.05
4 bedrooms	261	11.01
5+ bedrooms	52	2.19
1 bathroom	1055	44.51
2 bathrooms	950	40.08
3+ bathrooms	365	15.40
0 or 1 fireplace	2297	96.92
2+ fireplaces	73	3.08
	Mean	**Std. Dev.**
Price	$ 71,692.37	$ 37,785.67
Distance	3.61	1.00
Age	37.85	16.04
Acres	0.40	0.37
BlackPerc	46.72	30.66

Table 3: Base Model -- Full Sample -- 1995 Contours				
	Semi-Log		Linear	
	Parameter	| t |	Parameter	| t |
Noise65d_95	-0.026**	2.03	-3675.36***	3.22
Noise70d_95	-0.011	0.45	-1207.04	0.39
NoiseRegd	0.136***	10.37	10590.63***	8.70
Distance	-0.016	1.04	-2131.67*	1.73
Beds3d	0.080***	3.93	2650.78	1.35
Beds4d	0.161***	5.16	12397.86***	3.63
Beds5d	0.210***	3.14	23543.69***	2.60
Baths2d	0.165***	9.61	9324.92***	6.58
Baths3d	0.329***	10.10	25579.41***	7.05
Fire2d	0.240***	5.52	25058.19***	3.60
Storiesd	0.109***	3.22	15056.98***	4.78
Age	-0.002***	2.95	-139.97	1.60
Acres	0.104***	3.25	9285.77***	2.67
BlackPerc	-0.003***	3.77	-227.74***	4.14
City2d	0.181***	4.95	10172.96***	2.71
City3d	-0.078*	1.81	-8400.52**	2.18
City4d	0.266***	8.13	20095.15***	5.18
City5d	-0.092**	2.09	-10500.33***	2.67
City6d	0.038	0.62	-3331.17	0.54
Constant	11.032***	117.31	77245.03***	9.02
Observations	2370		2370	
R-squared	0.45		0.40	
Robust t statistics in brackets				
* significant at 10%; ** significant at 5%; *** significant at 1%				

Table 4: Summary Statistics, Reduced Sample -- 1643 Observations		
	Count	**Frequency**
House Sales in the buffer zone	1008	61.35
House Sales in 65 db zone	568	34.57
House Sales in 70 db zone	67	4.08
House Sales in Atlanta	92	5.60
House Sales in College Park	354	21.55
House Sales in Conley	252	15.34
House Sales in East Point	261	15.89
House Sales in Forest Park	532	32.38
House Sales in Hapeville	152	9.25
1 story	1475	89.77
2 or more stories	158	9.62
3 bedrooms	1057	64.33
4 bedrooms	190	11.56
5+ bedrooms	40	2.43
1 bathroom	1326	80.71
2 bathrooms	667	40.60
3+ bathrooms	270	16.43
0 or 1 fireplace	1579	96.10
2+ fireplaces	64	3.90
	Mean	**Std. Dev.**
Price	$73,624.65	$38,315.04
Distance	3.54	1.10
Age	39.05	17.52
Acres	0.41	0.38
BlackPerc	44.23	30.82

Table 5: Base Models – Adjusted Housing Prices								
	Semi-Log		Linear		Semi-Log		Linear	
	Parameter	| t |	Parameter	| t |	Parameter	| t |	Parameter	| t |
Noise65d_9503	-0.030*	1.76	-3962.4**	2.42	-0.028*	1.66	-3720.5**	2.19
Noise70d_9503	-0.063*	1.79	-9622.2***	3.49	-0.062*	1.73	-9553.4***	3.43
NoiseRegd	0.155***	9.55	11624.38**	7.61				
Distance	-0.047**	2.43	-3939.3**	2.48	-0.046**	2.41	-3829.7**	2.45
Beds3d	0.093***	3.73	3137.6	1.28	0.091***	3.66	3046.6	1.26
Beds4d	0.141***	3.64	11437.9***	2.67	0.141***	3.67	11487.0***	2.69
Beds5d	0.130*	1.67	13365.2*	1.91	0.129*	1.67	13387.0*	1.91
Baths2d	0.195***	9.25	11807.7***	6.89	0.194***	9.21	11743.3***	6.88
Baths3d	0.357***	10.14	27504.8***	9.36	0.354***	10.22	27373.6***	9.50
Fire2d	0.226***	5.10	20340.3***	4.54	0.216***	4.96	19817.4***	4.45
Storiesd	0.156***	4.65	16888.5***	5.11	0.147***	4.45	16405.1***	4.96
Age	-0.002***	3.14	-158.8**	2.08	-0.002***	3.24	-160.5**	2.13
Acres	0.113***	3.41	10794.6***	2.76	0.116***	3.54	10875.7***	2.80
BlackPerc	-0.003***	3.46	-251.7***	3.97	-0.003***	3.47	-250.6***	4.04
City2d	0.172***	3.89	10663.8**	2.38	0.177***	3.92	11196.6**	2.40
City3d	-0.068	1.24	-9579.7*	1.93	-0.065	1.19	-9365.3*	1.89
City4d	0.242***	6.15	17534.1***	3.73	0.243***	6.11	17592.0***	3.73
City5d	-0.082	1.58	-11361.3**	2.40	-0.084	1.61	-11438.9**	2.41
City6d	-0.033	0.48	-8612.8	1.25	-0.041	0.59	-9033.8	1.32
Constant	11.137***	100.62	84972.2***	8.74	11.052***	94.93	78888.5***	7.85
1996d					0.086**	2.17	5133.5**	2.13
1997d					0.066	1.53	5898.3*	1.66
1998d					0.063	1.57	3860.0*	1.68
1999d					0.156***	4.27	10352.8***	3.97
2000d					0.234***	5.57	17407.7***	5.19
2001d					0.243***	6.60	18343.0***	6.73
2002d					0.237***	6.44	16256.6***	5.95
Observations	1643		1643		1643		1643	
R-squared	0.47		0.42		0.48		0.42	
Robust t statistics in brackets								
* significant at 10%; ** significant at 5%; *** significant at 1%								

Table 6: Base Models – Nominal Housing Prices				
	Semi-Log		Linear	
	Parameter	| t |	Parameter	| t |
Noise65d_9503	-0.028*	1.66	-5340.1**	2.43
Noise70d_9503	-0.062*	1.73	-13351.2***	3.74
Distance	-0.046**	2.41	-5359.0**	2.55
Beds3d	0.091***	3.66	3553.7	1.13
Beds4d	0.141***	3.67	14751.2***	2.63
Beds5d	0.129*	1.67	14814.7*	1.65
Baths2d	0.194***	9.21	14953.0***	6.52
Baths3d	0.354***	10.22	34326.2***	8.84
Fire2d	0.216***	4.96	22669.6***	3.94
Storiesd	0.147	4.45	23899.0***	5.29
Age	-0.002***	3.24	-257.5***	2.58
Acres	0.116***	3.54	14851.3***	2.83
BlackPerc	-0.003***	3.47	-334.4***	3.99
City2d	0.177***	3.92	14587.7**	2.15
City3d	-0.065	1.19	-12981.7*	1.86
City4d	0.243***	6.11	21205.1***	3.25
City5d	-0.084	1.61	-15900.3**	2.34
City6d	-0.041	0.59	-13489.0	1.42
Constant	11.052***	94.93	89331.9***	6.52
1996d	0.118***	2.98	7663.7***	2.85
1997d	0.172***	3.98	13837.3***	3.44
1998d	0.231***	5.78	15798.2***	5.97
1999d	0.394***	10.78	29399.0***	9.48
2000d	0.531***	12.63	44704.1***	10.53
2001d	0.596***	16.21	52176.9***	14.89
2002d	0.644***	17.48	55702.5***	15.48
Observations	1643		1643	
R-squared	0.58		0.49	
Robust t statistics in brackets				
* significant at 10%; ** significant at 5%; *** significant at 1%				

Table 7: Model With Differential Effects - Adjusted Housing Prices								
	Semi-Log		Linear		Semi-Log		Linear	
	Parameter	| t |	Parameter	| t |	Parameter	| t |	Parameter	| t |
Noise65d_9503	0.013	0.53	47.05	0.02	0.014	0.61	337.4	0.15
Noise70d_9503	-0.021	0.39	-5657.98	1.53	-0.018	0.32	-5405.3	1.42
NoiseRegd	0.189***	8.95	14929.14***	7.48				
Noise65dDif	-0.091***	2.62	-8658.68***	2.81	-0.092***	2.63	-8716.1***	2.74
Noise70dDif	-0.092	1.51	-8671.62*	1.87	-0.097	1.53	-8988.2*	1.90
Distance	-0.045**	2.33	-3749.20**	2.35	-0.044**	2.31	-3641.5**	2.32
Beds3d	0.096***	3.86	3389.93	1.40	0.093***	3.80	3299.9	1.38
Beds4d	0.142***	3.68	11510.04***	2.69	0.142***	3.71	11562.4***	2.71
Beds5d	0.128*	1.66	13261.90*	1.89	0.128*	1.65	13271.2*	1.89
Baths2d	0.195***	9.31	11849.89***	6.93	0.195***	9.30	11836.5***	6.96
Baths3d	0.358***	10.18	27532.65***	9.37	0.355***	10.27	27427.2***	9.53
Fire2d	0.228***	5.07	20536.93***	4.54	0.217***	4.92	19945.2***	4.44
Storiesd	0.162***	4.85	17503.77***	5.29	0.154***	4.65	17072.0***	5.13
Age	-0.002***	3.08	-152.90**	2.01	-0.003***	3.17	-154.3**	2.05
Acres	0.110***	3.32	10475.24***	2.68	0.112***	3.45	10571.3***	2.72
BlackPerc	-0.003***	3.22	-235.74***	3.76	-0.003***	3.23	-234.9***	3.84
City2d	0.183***	4.11	11691.53***	2.63	0.187***	4.14	12208.6***	2.64
City3d	-0.063	1.14	-9109.94*	1.85	-0.061	1.09	-8899.3*	1.82
City4d	0.240***	6.10	17327.39***	3.70	0.241***	6.05	17367.7***	3.69
City5d	-0.075	1.43	-10628.59**	2.28	-0.076	1.46	-10693.3**	2.29
City6d	-0.018	0.27	-7202.01	1.06	-0.026	0.37	-7594.1	1.13
Constant	11.095***	100.69	81023.73***	8.55	11.008***	94.84	74757.8***	7.61
1996d					0.090**	2.29	5560.4**	2.32
1997d					0.071	1.64	6374.9*	1.77
1998d					0.060	1.52	3636.4	1.60
1999d					0.156***	4.29	10373.2***	3.99
2000d					0.271***	6.05	20954.0***	5.64
2001d					0.277***	6.87	21612.5***	7.01
2002d					0.275***	6.78	19859.8***	6.45
Observations	1643		1643		1643		1643	
R-squared	0.47		0.42		0.48		0.43	
Robust t statistics in brackets								
* significant at 10%; ** significant at 5%; *** significant at 1%								

Figure 1
The Location of Hartsfield-Jackson Atlanta International Airport

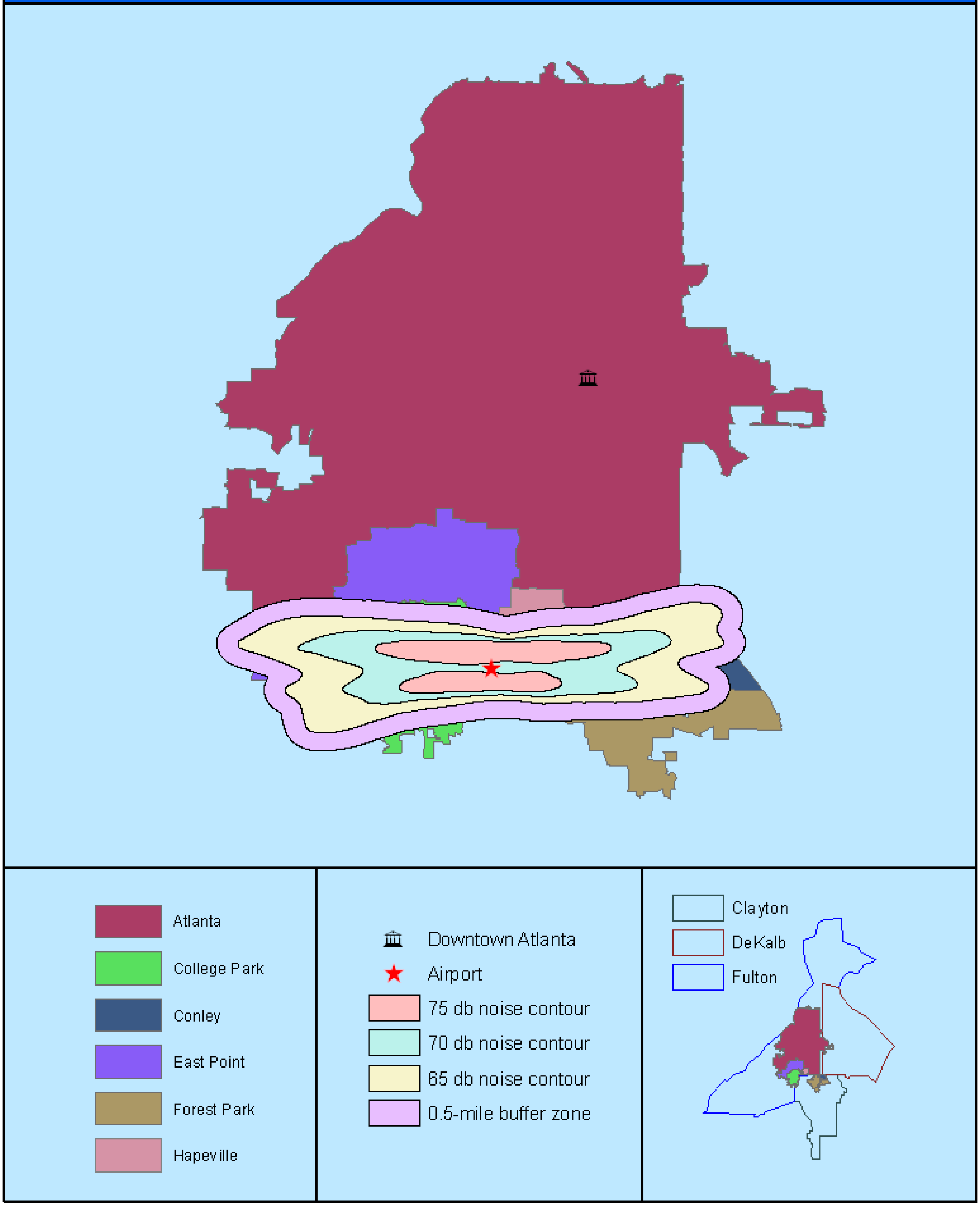

Figure 2
The Location of Houses in the Full Sample

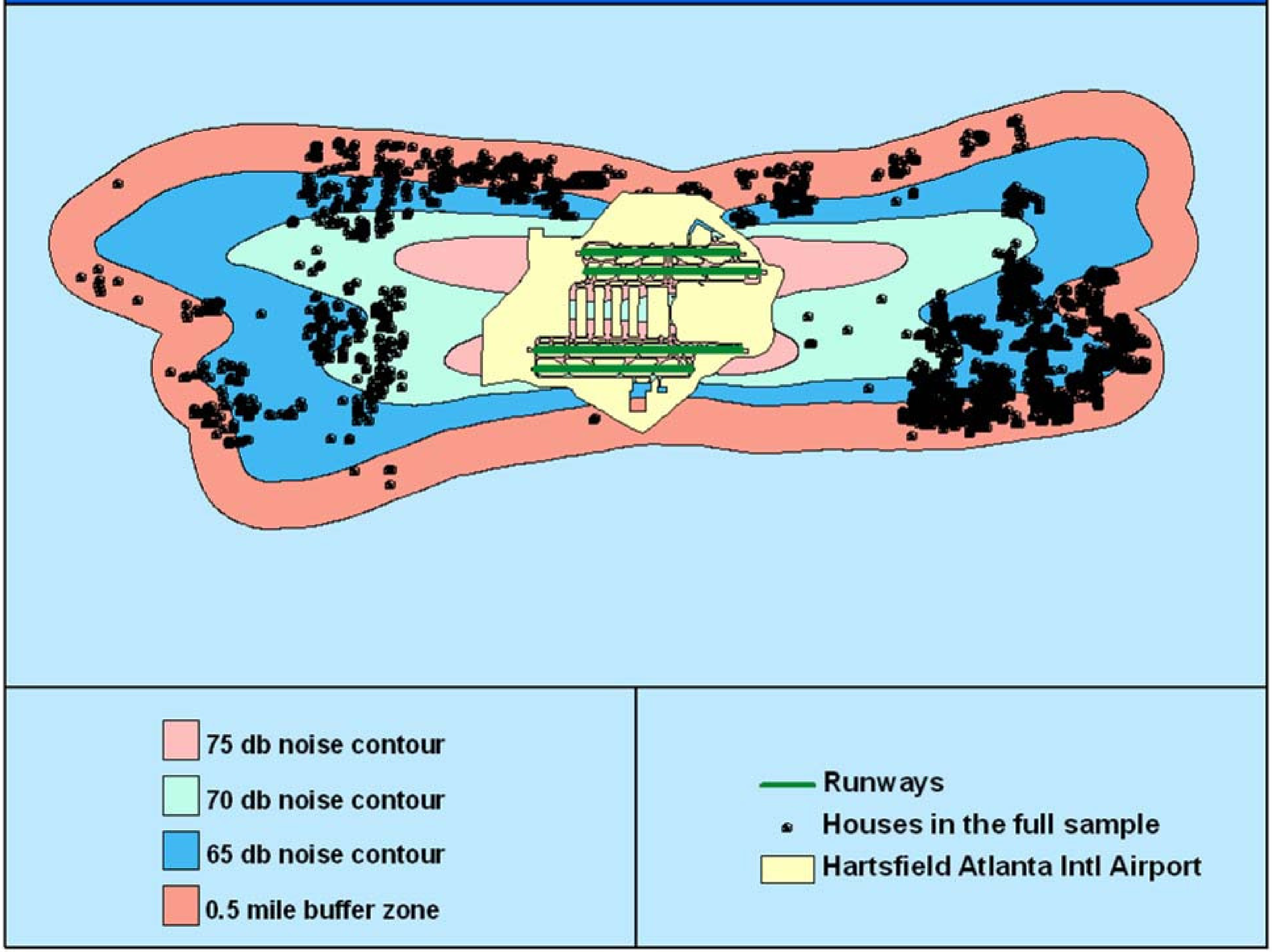

Figure 3
The Shift of the 65 Decibel Noise Contour: 1995 Versus 2003

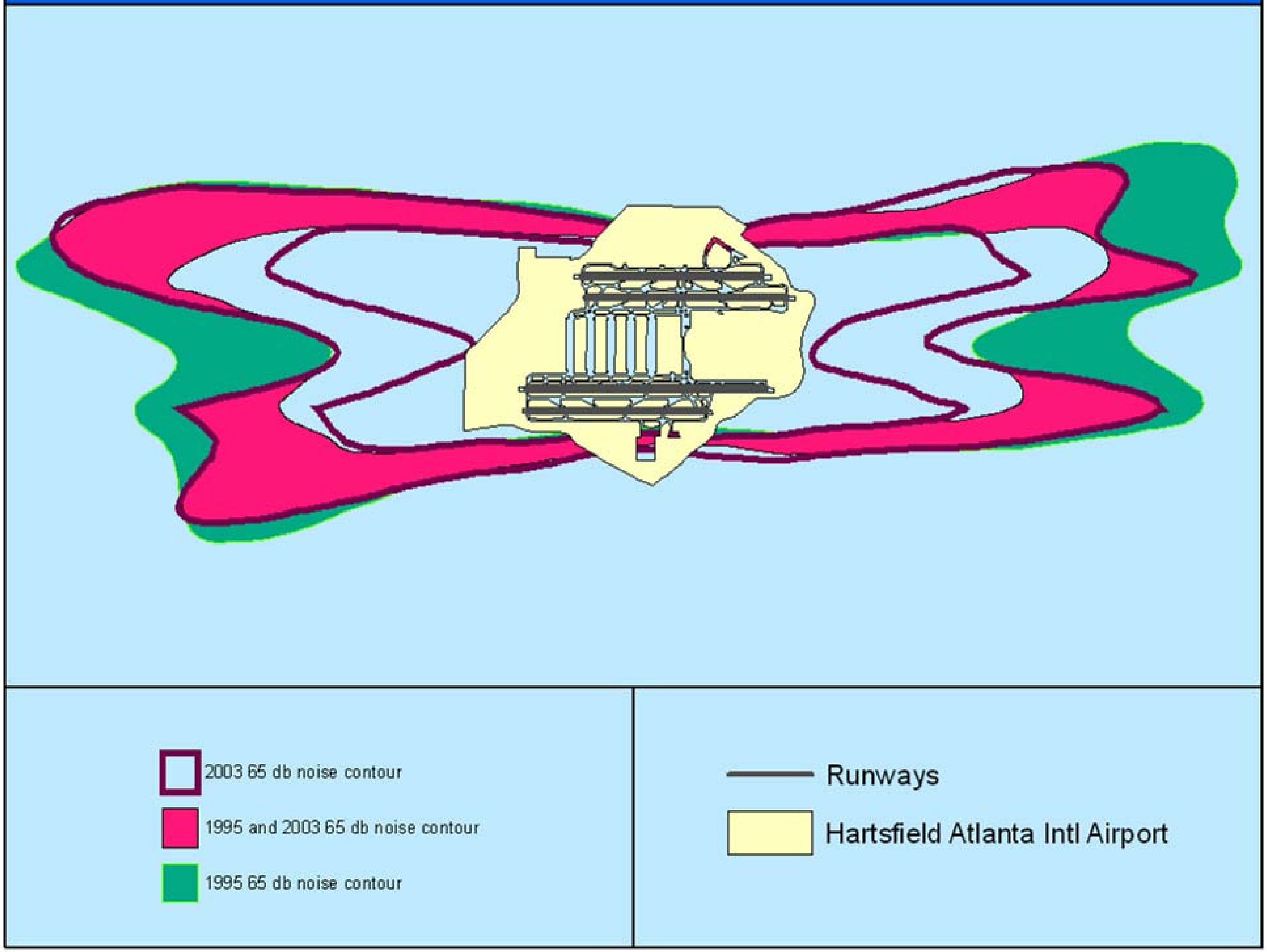

Figure 4
The Location of Houses in the Reduced Sample