Perception vs. Reality:
The noise complaint effect on home values*

by

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Abstract

Aircraft noise pollution adversely affects physical and mental health. Previous research quantifies the costs of this disamenity through the losses that are capitalized into home values. Much of this research relies heavily on spatially restrictive noise contour plots to identify the house price discounts and determine economic damage. We break new ground on this subject by investigating whether actual residential noise complaints more accurately measure the aircraft noise pollution and housing price impacts experienced by residents near Minneapolis-Saint Paul International Airport. Our findings indicate that noise complaints are a reliable measure of residential noise annoyance and have a significant adverse effect on home prices that extends more than twice as far (12 km) as the contour estimates. Reevaluating the economic damages based on our novel results provides consistent evidence that contour-based calculations severely underestimate the aircraft-noise-pollution-induced losses incurred by homeowners and suggest that $134 million of $146 million in damages are borne by residents located outside the regulated Minneapolis contour area.

JEL codes: (R2, R3)

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Introduction

Disamenities, such as aircraft noise pollution, can adversely affect physical and mental health.[4] Proximity to such noise can decrease the desirability of living near the noisy location. In turn, this can impact the value of houses, as reflected by their sales prices. If one considers noise as an undesirable characteristic of a house, one can rely on the more general work by Rosen (1974), which postulates house values are comprised of the value of their characteristics, to value the noise disamenity. Banzhaf and Farooque (2013) provide a recent overview of how environmental amenities and disamenities, more generally, are incorporated into the hedonic framework.

An established body of research has made important advances in quantifying how aircraft noise is capitalized into home sale prices (see, for example, Pope (2008); Boes and Nüesch (2011); Espey and Lopez (2000); Cohen and Coughlin (2008)). Much of this previous research estimating these noise pollution home discounts, including Friedt and Cohen (2019) among others, relies heavily on noise contour plots to identify the relevant local levels of noise pollution. These federally regulated contour plots, however, are based on mathematical models that depend on estimates of the average decibels of day-night average sound levels (abbreviated as DNL), and do not necessarily measure the actual noise annoyance levels experienced by local residents at one particular time during the day or season of the year (Schomer, 2005). Moreover, the noise contour plots tend to be geographically restricted, only including areas that experience aircraft noise pollution in excess of the relevant thresholds deemed significant by the respective regulators (often starting at 55 DNL or higher). As a result, contour plots may be imprecise estimates of individual residential noise experience and underestimate the adverse effects of aircraft noise pollution in some locations as well as at times of day when flight traffic is particularly high.

As one might suspect, the contour thresholds of what is considered significant and harmful aircraft noise pollution, in fact, vary across countries. In the United States, in the case of aircraft noise, 65 dB DNL is deemed to be disruptive of sleeping, thinking, and conversations (FAA, 2000) and has therefore been set as the significant threshold of aircraft noise pollution by the Federal Aviation Administration (FAA) (FAA, 2018). Many U.S. airport authorities, however, publish contour curves that indicate noise pollution below this threshold at the 60 or even 55 dB DNL. In contrast, the European Union Aviation Safety Agency (EASA) has defined two significant noise thresholds: one at the 55dB sound pressure levels averaged over the year for the day, evening and night time periods and the other at the 50dB sound pressure level averaged over the year during night time periods only (EC, 2002). At such peak times, when sleeping and normal conversations are disrupted, residents may be inclined to file complaints.

More recently, the World Health Organization Europe (WHOE) has released new guidance that recommends the reduction of these thresholds deeming daily average aircraft noise annoyance significant above 45dB and nighttime sleep disturbance significant above 40dB (WHOE, 2018). These revisions of what constitutes harmful levels of average noise are indicative of the fact that the human experience of aircraft noise pollution is perhaps not effectively captured by the existing noise contour plots and that the resulting adverse health implications are unlikely to be constrained to the residents living within the geographic areas identified by noise contours. Since the regulation of aircraft noise and

[4] Schlenker and Walker (2015) find that heart and pulmonary patient health care treatment costs rise by over half of a million dollars for a one-standard deviation in air pollution near airports in California.

noise mitigation policies tend to be based on these contour plots (MAC, 2019a), the implications of these potential disconnects can be significant.

To overcome these limitations and test whether aircraft noise exposure, indeed, has adverse implications beyond the traditional contour plots, we exploit resident noise complaints as an alternative measure of aircraft noise pollution. We employ our novel approach in the context of Minneapolis and estimate the complaint effect on Minneapolis home values from 2006 through 2017. We find convincing evidence that noise complaints are indeed an effective measure of aircraft noise pollution and cause consistent as well as economically significant home value discounts that reach far beyond the regulated contour plots. Specifically, we find that a 10% increase in annual local noise complaints reduces property values by around 0.05%, on average, and that this noise pollution effect, persists for more than 12 kilometers (km) past the airport – more than twice the distance of the outer most contour curve.

In comparison to the more traditional approach that identifies noise pollution via noise contours, we find that noise complaints have nearly identical prediction accuracy of sale prices among home sales within the contour sample and represent a consistent measure of noise pollution beyond these thresholds. Against the counterfactual of zero residential noise complaints, we estimate that aggregate economic damages, due to aircraft noise pollution attributable to the Minneapolis-Saint Paul (MSP) International Airport, amount to $146 million (measured in 2017 $'s) in lost home value on Minneapolis home sales during our 2006 through 2017 sample. More importantly, we find that less than 10% of these losses occur for homeowners experiencing noise pollution above the 'significant' noise thresholds, whereas residents selling homes outside of the traditional contour plots shoulder more than 90% of the noise pollution damages. Our estimates seem reasonable given that the Metropolitan Airport Commission (MAC) has already invested around $95 million in a noise abatement program over the last decade to mitigate losses from noise pollution experienced by homeowners located within the MSP contour curves. Overall, the $134 million of out-of-contour losses and $12 million of within-contour damages account for around 1% to 2% of the overall sale value. Again, we view this as a reasonable approximation based on our estimated sale price discount of 0.5% per dB DNL of aircraft noise pollution within MSP contour plots, which agrees with much of the previous literature.

The noise complaint data underlying these results are comprised of nearly 1,000,000 observations that represent daily-recorded phone calls or electronic submissions of resident complaints from the greater Twin City's metropolitan area from 2006 through 2017. Of these, around 310,000 complaints are attributable to Minneapolis home owners and approximately 125,000 fall within the noise contour plots. More than half of these Minneapolis complaints, however, are recorded outside of any contours, which is suggestive of the considerable residential noise annoyance ignored by the regulators' noise models. To remain anonymous complaints are recorded over a pre-specified grid rather than individual parcels and to develop our novel datasets we match annual grid-level complaints with contour noise and 41,275 Minneapolis homes sales from 2006 to 2017.

Taking advantage of the temporal and spatial variation in measurable noise annoyance within and beyond contour plots, we break new ground on quantifying the adverse aircraft noise pollution effects. We investigate whether the MSP noise contour plots truly capture the actual noise experience that lead to house price discounts, or whether noise complaints are a more accurate measure of the actual aircraft noise pollution experienced by residents. Our results are fourfold. First, we find convincing evidence that noise complaints are strongly and positively correlated with aircraft noise pollution indicated via noise contour plots, and also convey a substantial amount of information on the residential experience of noise pollution beyond these federally regulated thresholds.

Second, controlling for home and neighborhood characteristics, as well as noise abatement eligibility among properties, we provide robust evidence that a one dB DNL increase in contour-measured noise pollution lowers home values by 0.5%. Our estimate agrees with much of the previous literature (see, for example, Boes and Nüesch (2011)). Similar to Friedt and Cohen (2019), we find that abatement eligibility (and eventual sound insulation) more than compensates homeowners for the experienced aircraft noise pollution.

Third, when we identify aircraft noise pollution via residential noise complaints, we find robust noise-induced sale price discounts on homes both inside and outside of the MSP contour plots. Our estimates suggest that a 100% increase in local annual noise complaints lowers home values by 0.5% on average and that this adverse effect persists more 12km away from the airport. In contrast, the maximum distance of homes affected by aircraft noise pollution according to MSP contour curves is less than 6km.

Fourth, in the presence of sound insulation subsidies for Minneapolis homes located within contour plots, we find that 90% of the economic damages due to MSP aircraft noise pollution are, in fact, borne by homeowners located outside the federally regulated thresholds. Based on our estimates, this suggest that $134 million of the total 2006 through 2017 economic loss of $146 million fall on residential homeowners that are ineligible for noise abatement.

Based on these findings, our study contributes to literature in several ways. First, the methodology of measuring aircraft noise using complaints is unique, and we develop a new dataset that utilizes complaints data. In addition to the evidence we generate that supports the findings of previous contour-based findings, our empirical results provide more comprehensive noise information than would be possible with noise contour studies that start measuring noise at 50 dB DNL or 55 dB DNL as the lower bounds. We are also able to compare our estimates from complaints data with the estimates from noise data, and this leads to new insights on the distribution of noise pollution effects between contour and non-contour areas. Finally, our findings have policy relevance that can help airport planners as well as individuals deciding how and by how much to compensate affected homeowners.

The remainder of this paper continues as follows. First, we review the relevant literature on airport noise studies, followed by a discussion of our approach to address the issue. Next, we present summary statistics of our dataset and describe our data sources, followed by the presentation of our estimation results. Finally, we conclude by summarizing our findings and discussing potential policy implications of our results.

Literature Review

The vast majority of the airport noise impacts on house prices literature focuses on measured noise levels, opposed to complaints. For instance, Cohen and Coughlin (2008) consider how noise near the Atlanta airport impacted house prices, and find that single-family residential properties within the 65 dB noise contour sold for approximately 20 percent less than those properties in a buffer zone of 55 dB or less. There are a vast number of other hedonic studies that follow similar approaches, such as Espey and

Lopez (2000), who focus on the Reno-Sparks airport. Nelson (2004) is a meta-analysis that integrates many hedonic airport noise studies, and he finds that among over 20 different studies, the country in which the airport is located and the model specification are the most important determinants of the noise discount.

More recently, Friedt and Cohen (2019) consider a hedonic model of the Minneapolis/St. Paul airport, with an identification strategy that is based on soundproofing eligibility. They find properties that were not eligible for abatement experienced a 2 percent discount over a 3-year period before their sale, while those properties eligible for abatement did not experience any significant discount. Using spatial econometric techniques, Affuso et al. (2019) find slightly less than a $5,000 discount per decibel of noise near the airport in Memphis, TN.

These U.S. airport noise findings are somewhat robust in studies of other countries. For instance, Boes and Nüesch (2011) find that property values fall by approximately 0.5% for every one decibel increase in noise near the Zurich, Switzerland airport. As an alternative to considering direct estimates of noise in a European context, Mense and Kholodilin (2014) find that residential properties within newly announced flight paths near the airport in Berlin, Germany experienced price decreases in the range of 8%-13%. Also in the Berlin, Germany context, Ahlfeldt and Maennig, (2015) consider a referendum on a new "airport concept". They use a hedonic approach with a noise level variable (above 45 dB) for the two existing airports that were to be replaced (and an indicator for being in a noisy area for a third airport), each interacted with a dummy variable for the 1996 announcement date of the new "airport concept". Ahlfeldt and Maennig, (2015) find highly significant (and positive) treatment effects from the announcement of this concept. In other words, expectations of less noise after the closure of the old airports was reflected in higher residential property values in the areas of the old airports.

There are some other approaches that have been considered to estimating the impacts of noise. For instance, Weinhold et al. (2013) conducts a "happiness study" to assess how perceptions of noise impact happiness. They translate these happiness impacts into Euros and find that the typical monthly cost of noise pollution is approximately 172 Euros. But this is not a hedonic study. Nevertheless, the approach of Weinhold et al. (2013) implies that other noise metrics, besides contours that are estimated by the airport authorities, are worthy of consideration. Sobotta et al. (2007) indicate how several reports by U.S. federal government agencies (such as the Government Accountability Office and the Environmental Protection Agency) highlight that airport noise contours underestimate the level of noise exposure by residents. This underscores the potential importance of considering other metrics, such as complaints. There are also some studies that have focused on complaints. Gillen and Levesque (1995) find that the probability of additional complaints is increasing with the level of noise near airports, as well as with several other economic and socio-economic variables. Maziul et al. (2005) find complaints are not necessarily a reliable proxy for annoyance, and other factors should be taken into consideration. Fan et al. (2019) examine noise complaints from bus transit routes in Singapore, using a two-step approach. First, they estimate how transit impacts noise complaints. In their second step, they estimate how the fitted value of noise complaints impacts house prices. They find that for every 1% increase in complaints, house prices fall by approximately 3%.

For these reasons outlined in the above studies, a regression analysis of how the probability of additional complaints depends on noise levels and other variables is the approach we consider below. After we demonstrate the high correlation between noise and the probability of additional complaints, we utilize hedonic methods and complaints as our noise proxy to assess how complaints impact property values.

Approach

Integrating the approaches of several others in the literature, including Gillen and Levesque (1995) with the hedonic literature, our approach is as follows. We consider two different angles to be explored in our paper; first, how observed noise levels are correlated with complaints; and second, how complaints impact house prices.

Noise Contour and Complaint Correlation

The MAC launched its noise complaint program in 2006 and has since established a 24-hour noise complaint and information hotline. The expressed goal of this initiative is to use these complaints data to "log, monitor and analyze concerns of airport neighbors, identify trends, and communicate with customers about their concerns." (MAC Noise Program Office, 2018). Since its inception, the MAC has reported that complaint data are also used by "some city governments […] to gauge the level of concern about aircraft noise in their communities." (MAC, 2019b). To register a complaint with the MAC, a resident can call or file an electronic complaint report (see Figure 4 in the appendix) and must provide "a location of the aircraft activity and details about the aircraft activity such as date, time, and description of the activity of concern." (MAC Noise Program Office, 2018). According to the 'Aircraft Activity Complain' guidelines, a person may file several noise complaint, each of which will be logged for the respective noise events identified in the report. Failure to provide a valid address of the complaining resident or any of the specifics related to the noise event, however, will terminate the complaint.

To establish whether these noise complaints are a indeed a good measure of aircraft noise pollution and a feasible alternative to noise contour plots, we begin our analysis by investigating whether the mathematically modeled and traditionally used noise contours have any predictive power over noise complaints. Our baseline approach to establish this contour-complaint correlation employs the Ordinary Least Squares (OLS) estimator. Specifically, we model annual (y), grid-level (g) noise complaints (C_{gy}) as function of annual grid-level contour noise pollution (N_{gy}) and other characteristics, including total population (Pop_{gy}) and the percentage of the population that is white (W_{gy}).[5] Moreover, we control for overarching trends, such as the rising popularity of the noise complaint program, via year fixed effects (α_y).

Our full model also controls for the fact that a specific set of residents potentially benefitted from a noise abatement program initiated by the MAC in 2007 and concluded in 2014. Under this initiative, abatement eligibility as well as the amount of sound insulation subsidies depend on aircraft noise pollution measured via the 2007 MSP contours.[6] The receipt of such subsidies, or even anticipation thereof, may also alter the noise complaint behavior of the affected residents under various levels of

[5] Since these characteristics, including contour noise, are not originally reported at the grid level, we compute these statistics using spatially weighted averages of the relevant variables. In the next section, we provide further details on these calculations.

[6] For more detailed background knowledge and estimations of the effect of this noise abatement program, we refer the interested reader to Friedt and Cohen (2019).

experienced noise pollution and therefore necessitates the interaction of abatement eligibility (δ_{gy}) with contour noise pollution in our model. Consequently, our baseline OLS model can be expressed as follows:

$$C_{gy} = \beta_0 + \beta_1 N_{gy} + \beta_2 Pop_{gy} + \beta_3 W_{gy} + \beta_4 \delta_{gy} x N_{gy} + \alpha_y + \varepsilon_{gy} \qquad (1)$$

Departing from this baseline specification, we acknowledge that noise complaints are perhaps more appropriately modeled as a count variable and that many of the annual grid-level complaint observations are zero valued. Because of these features of our data, we explore the robustness of our initial OLS results against the application of alternative estimators that may be better suited to model the complaint data. A model comparison between the original OLS specification and multiple count models, including the Poisson (PRM), Negative Binomial (NBRM), and Zero-Inflated Negative Binomial (ZINB) estimators, reveals that ZINB is, in fact, the most appropriate technique given our data. Both the Akaike (AIC) and Bayesian Information Criteria (BIC) reported in Table A7 in the appendix strongly suggest the use of ZINB.

The critical distinction of the ZINB estimator lies in the treatment of the disproportionate number of zeros. Under ZINB, the researcher assumes that there are two processes producing these zero-valued observations. In our context, one might argue that one of these processes that creates zero grid complaints arises as result of negligible noise pollution experienced by local residents. These observations, in fact, represent meaningful zeros with regard to the aircraft noise pollution information conveyed in residential noise complaints. The other processes that create zero-valued complaint observations, however, arise in the presence of significant noise pollution when there is an absence of local residents and/or a lack of knowledge about the MAC's complaint program among the adversely affected residents. These possibilities can create zero-inflating data generating processes that we explicitly model via the ZINB estimator. In our context, we model average grid complaints of the log-likelihood function as dependent on the aforementioned noise and demographic grid-level characteristics, as well as year fixed effects as given in Equation (1). In contrast, the zero-inflating process is modeled as a function of the number of potential complainers, measured by grid-level population, and year fixed effects to account for the increasing popularity of the complaint program.

The Hedonic Model and Noise Complaints

After investigating and uncovering the expected positive correlation between noise complaints and noise pollution measured via MSP contour curves, we proceed in our analysis with an estimation of the adverse noise pollution externalities capitalized in house values. To this end, we build on the hedonic literature and model the log of home i's sale price at time t ($\ln(P_{it})$) as a function of annual neighborhood characteristics (BGC_{bt}), including block-group (b) population and the percentage of white block-group residents. Additionally, we control for time-invariant housing characteristics (H_i), such as the year a home was built, the number of bedrooms, bathrooms, and fireplaces, as well as the parcel's square footage. Macroeconomic housing market trends and seasonality of house sale prices are captured via year (α_y) and month (α_m) fixed effects, respectively.

Conditional on these control variables, the primary relationship of interest determines the home value discount with respect to aircraft noise pollution. In line with the previous literature, we begin by measuring home-specific noise pollution in annual dB DNL (N_{it}) by mapping a parcel's location relative to the model-based MSP contour plots. Akin to the previous analysis, we differentiate these adverse noise effects across homes that are abatement eligible (δ_{iy}) and those that are not. The resulting estimation equation is given by

$$\ln(P_{it}) = \beta_0 + \beta_1 N_{it} + \beta_2 \delta_{it} x N_{it} + \beta_3 BGC_{it} + \beta_4 H_i + \alpha_y + \alpha_m + \varepsilon_{it} \qquad (2)$$

and is restricted to a sample of home sales located within MSP contours.

Extending the work of the previous literature, we depart from the restrictive noise contours and identify aircraft noise pollution via annual, residential noise complaints (C_{it}) instead. Given the wide dispersion of our complaint data, we log noise complaints and only consider house sales in the vicinity of complaining homeowners.[7] Similar to the previous specification, we delineate the complaint effect across homes that are abatement eligible and those that are not. Unlike the contour-based noise pollution approximations, noise complaints are not limited to the geographic area directly surrounding the airport and instead span across a multitude of communities. To capture the inherent differences in house sale prices across these neighborhoods, we further integrate community fixed effects (α_{com}) into the complaint specification. The primary estimation equation is given by

$$\ln(P_{it}) = \beta_0 + \beta_1 \mathrm{C}_{it} + \beta_2 \delta_{it} x \mathrm{C}_{it} + \beta_3 BGC_{it} + \beta_4 H_i + \alpha_y + \alpha_m + \alpha_{com} + \varepsilon_{it}, \qquad (3)$$

where ε_{it} represents the random error component.

Data

In order to evaluate the capacity of residential noise complaints in identifying aircraft noise pollution and quantifying the resulting home price discounts, we obtain multiple datasets on noise complaints, contour curves, home sales, as well as parcel and block group characteristics from a variety of sources. We combine this information into two novel datasets aggregating information at the grid and property levels, respectively. We begin by discussing the construction of the grid-level data and highlighting a few key features. We, then, focus on the primary property-level dataset and provide a detailed summary of these data.

Grid-Level Data:

The key variables of interest are given by Minneapolis homes sale prices, residential noise complaints, and contour curves for MSP. Information on noise contours and complaints are published by the MAC and span a time period from 2006 to 2017. Noise contours, which measure the annual average Day-Night Sound Levels produced by aircrafts passing through MSP, are available at an annual frequency and distinguish noise pollution from the lower 60 dB DNL threshold to an upper limit of 80 dB DNL, typically disaggregated into one dB DNL increments.[8] Figures 1.1, 1.3, and 1.5 illustrate the outermost 60 dB DNL

[7] We carefully define our local measure of noise complaints and its mapping against house sales in the next section.

[8] For the years of 2007 through 2009, MSP contours only distinguish aircraft noise in 5 dB DNL intervals at 60 dB, 65 dB, 70 dB, and 75 dB DNL. For all other years, the MAC produces MSP contours differentiating aircraft noise pollution at the one dB DNLs between 60 dB and 80 dB.

contour curve approximating MSP aircraft noise pollution relative to the seven Minnesota counties surrounding the airport in 2006, 2011, and 2016, respectively. Among our sample of Minneapolis home sales located within these contours, aircraft noise pollution, measured via contours, averages 62.1 dB DNL and ranges from a minimum of 60 dB DNL to a maximum of 71 dB DNL in 2006 (Panel B, Table 1). Given the geographic limitations of these contour curves as depicted in Figures 1.1 through 1.6, we can associate this type of noise measurement with only 3,644 home sales out of 41,275 total transactions. On average, these properties are located about 2.8 km from the airport, with a maximum distance of 5.9 km from MSP.

[INSERT FIGURES 1.1 TRHOUGH 1.6]

In contrast, the MAC records residential noise complaints at an hourly frequency and maps this aircraft noise annoyance measure into 7,402 sample grids spanning over the seven counties of the greater Twin Cities metropolitan area (see, for example, Figures 1.1). In total, the MAC has recorded nearly 1,000,000 residential noise complaints during the 2006 to 2017 sample period, around 310,000 of which occurred in Minneapolis alone. In order to create a complaint noise measure comparable to contour DNLs, we aggregate these real-time grid-level noise complaints to an annual frequency. We argue that an annual complaint count is a more appropriate measure of aggregate residential noise annoyance than contemporaneous complaints during the day or even month of a property's sale. Figures 1.1 through 1.6 depict the spatial distributions of these grid-level complaints (relative to noise contours) over the seven Minnesota counties surrounding MSP and the Minneapolis communities for 2006 (Figures 1.1 & 1.2), 2011 (Figures 1.3 & 1.4), and 2016 (Figures 1.5 & 1.6).

The graphs communicate three primary facts. First, we observe that noise complaints are more heavily concentrated in close proximity to the airport. As expected, noise complaints rise with aircraft noise, which increases near the airport as aircrafts operate in lower altitudes to approach or depart from MSP. Second, the figures clearly indicate that a significant degree of residential noise annoyance is reported beyond the lower 60 dB DNL threshold represented by the outer most contour. Based on our sample, nearly 750,000 of the recorded complaints are attributed to grids that do not overlap with noise contours. This accounts for more than 80% of the total number of complaints. Accordingly, one might argue that the human experience and discontent with aircraft noise is not bounded within the 'significant' noise thresholds set by regulators and that the adverse implications of noise pollution may reach much farther than indicated by traditional contour curves. Lastly, we also observe that the number of residential noise complaints rises over time. This might suggest that aircraft noise pollution increases over time and/or that the popularity of the complaint program rises among Twin City residents.

In panel A of Table 1, we provide further details on annual grid-level complaints as well as summary statistics on grid-specific characteristics, such as contour-based noise pollution, the number of home sales, and total population per grid. Both, the contour-based noise pollution and demographic characteristics are spatially-weighted averages, where the weights represent the share of the grid overlapping with a specific contour curve or specific 2010 Census block group. The statistics reveal that the average grid records 10.5 complaints per year, but that the distribution of complaints is over dispersed ranging from zero annual grid complaints to over 24,000 with a standard deviation of 214.64. Most of the 88,824 grid-year observations, in fact, indicate no aircraft noise complaints. Among the grids for which the MAC reports annual grid complaints, the average number of incidents reaches 190, with a median of eight and an interquartile range of 53. In Minneapolis, grid complaints average 146 per year with a standard deviation of close to 700 annual complaints.

[INSERT TABLE 1 HERE]

In line with the fact that noise complaints are rare and heavily concentrated among grids in close proximity to the airport, panel A of Table 1 further reveals that most grids do not intersect with any contour curves and that annual contour noise averages merely 0.34 dB DNL per grid. A calculation of the complaint-to-contour-noise ratio supports our initial hypothesis that noise complaints are positively correlated with the traditional measure of aircraft noise pollution. Among the 895 annual grid observations that overlap with noise contours we observe around 400 residential noise complaints per dB DNL, on average. Among Minneapolis grids, the mean of this ratio rises to nearly 1,200 complaints per dB DNL. Interestingly, even among these contour-overlapping grids, we observe some areas without any noise complaints, which might be the result of the absence of residents and/or the successful implementation of the aircraft noise abatement program alleviating the residents' noise annoyance.

Additional statistics that characterize our sample of annual grids include the number of Minneapolis house sales, the size of the grid population, and the percentage of grid population that identifies as white. On average, we observe 23.5 home sales per Minneapolis grid per year, while the full distribution ranges from zero to 168. Based on the 2010 U.S. Census and 2013 through 2017 American Community Surveys, we approximate annual grid-level population at 387 for the average grid and more than 8,600 for the most populous one. Among this grid population, roughly 90% consider themselves Caucasian on average, with a range from 10.67% to 100%.

Property-Level Data

We utilize this initial, grid-level dataset to estimate the relationship between residential noise complaints and contour approximated noise. The goal of this exercise is to test whether these two measures of aircraft noise pollution and noise annoyance coincide and whether noise complaints represent a reasonable measure to approximate noise pollution beyond the contour curves. In conclusion of this exercise, we turn towards an estimation of the noise complaint effect on home values. To this end, we develop a second, property-level dataset that matches noise complaints, contour noise, block group and home characteristics to the individual Minneapolis house transactions from 2006 through 2017.

Similar to mapping house sales to aircraft noise pollution based on contour curves, our annual complaint counts create a few challenges. Since residential noise complaints are recorded at a grid level to preserve anonymity, we can associate each home sale with a specific grid, but are unable to match complaints directly to the individual properties. These varying levels of aggregation are of no consequence if residential noise complaints are uniformly distributed within each grid, but can be problematic if complaints are geographically concentrated within grids.[9] This issue is, of course, not unique to grid-level noise complaints, but also arises in the contour case, where geographically

[9] Take for example a grid with a large volume of heavily concentrated annual complaints and a home sale within the same grid that falls outside of this area. In this case, we would falsely attribute significant noise complaints to this property, while in reality this transaction was perhaps less affected by the indicated noise annoyance. Similarly, a complaining homeowner may be located in a grid with few noise complaints overall, but still experience significant aircraft noise pollution in a spatially concentrated but small area relative to the grid. Under both of these circumstances, our estimate of the true noise pollution effect on home values would be biased. The direction of the bias tends downwards in first case and upwards under the second scenario.

continuous aircraft noise pollution is approximated via discontinuous DNL thresholds. The problem is most pronounced at the outer most contour curve, where residents just inside of the barrier are approximated to experience noise pollution at 60 dB DNL, whereas homeowners just outside this contour appear to experience zero noise pollution according to the contour map. True aircraft noise pollution is, of course, continuous across these thresholds. Remedies for this exacerbated discontinuity in the contour case are not obvious and the persistence of this issue has led to the reevaluation of significant noise thresholds in Europe (WTOE, 2018).

In the case of noise complaints, we argue that we can mitigate this issue and create a more holistic measure of local aircraft noise pollution by determining the 'local' level of noise complaints for each unique property. To this end, we identify the nearest four grids to each parcel and calculate the house-specific inverse-distance-weighted aggregate noise complaints across these four grids. We argue that this measure of 'local' noise complaints is a better representation of local aircraft noise annoyance and smooths out the spatial discontinuities given by grid boundaries. In other words, we integrate a larger set of information on noise complaints recorded within each property's vicinity (not just its grid), which we believe is much less susceptible to the previously indicated issue. Consider, for example, the case of noise pollution mismeasurement, where a significantly noise-polluted home is situated near the edge of a grid and appears to face low exposure to aircraft noise due minimal grid-level noise complaints. Since the surrounding grids closest to this particular property are likely to reflect a similar level of noise annoyance as experienced by the edge-case property, our local complaint measure would reduce the mismeasurement aggregating across all four grid complaint counts.[10]

As illustrated by Panel B of Table 1, aggregation over the nearest four grids takes account of the local geography of noise complaints smoothing out local outliers and accentuating broader trends of low to high levels of noise annoyance. The average Minneapolis home in our sample is located in a grid recording around 286 annual complaints, whereas the distance-weighted measure indicates an average of 301 local noise complaints. Similarly, the interquartile range (IQR) for local noise complaints (168.2) is slightly larger than its grid-specific counterpart (156.0). The maximum value of 97,962 noise complaints for the weighted aggregate, however, indicates that the severity local aircraft noise pollution may be much greater for certain areas than indicated by the grid-specific complaint count with a maximum value of 20,666.

The outcome variable of interest is given by Minneapolis home sale prices from 2006 through 2017. These data were generously provided by Professor Sarah West and Clemens Pilgram, who study the housing price premiums of the Minneapolis Blue Line light rail (Pilgram and West 2018) and were originally obtained from the City of Minneapolis' Tax Assessment Office. The records include all arm's length transactions of single-family home sales in Minneapolis between 2000 and 2017.[11] Given the availability of noise complaint data, however, we restrict the sample to market transactions from 2006 to 2017. The remaining sample includes 32,433 properties for which we observe a unique identification number and the corresponding home address, the date(s) of sale, and the nominal sale price(s). We adjust the nominal sale prices for inflation via the Consumer Price Index for all Urban Consumers, sourced from the Bureau of Labor Statistics (BLS), and express real property values in 2017 U.S. dollars.

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[10] Reassuringly, all of our results are quantitatively and qualitatively consistent when limiting the number of the complaints to the specific grid a given property is located in.

[11] To ensure the arm's length property of our data, we exclude outliers in the top and bottom 1% of sale price distribution. Specifically, we exclude 14 transactions valued above $3,000,000 and four transactions valued below $10,000. Our findings do not depend on these exclusions.

Panel B of Table 1 illustrates that the average Minneapolis home in our sample commands an average sale price of around $283,000 and ranges from $16,000 on the lower end to $3 million at the upper end of the distribution. Most of these Minneapolis homes report a single sale during our 2006 to 2017 sample period, while the most frequently sold property reports a total of six transactions during this timeframe. Among the repeatedly sold homes, Panel C of Table 1 shows that the duration between sales averages around 60 month and that the number of local noise complaints between these transactions tends to increase by around 280 records, on average.

Based on the unique parcel identification numbers, we are able to match the latest information on parcel characteristics using the 2019 *Assessor's Parcel Data* publicly available through the Open Minneapolis database published by the City of Minneapolis. The relevant control variables include, for example, the number of bedrooms, bathrooms, and fireplaces, as well as the each parcel's square footage and the year it was built. Panel B of Table 1 shows that the average Minneapolis home in our sample was built in 1940, offers two to three bedrooms and around two bathrooms, and sits on average parcel of 18,105 square feet located about 6 km away from the MSP international airport.

Additional control variables include neighborhood characteristics that are drawn from the 2010 U.S. Census and complemented by the estimates provided by the American Community Survey 2013 through 2017. The information is disaggregated at the block group level and includes the total block group population as well as the percentage of the population that identifies as Caucasian. To attribute these neighborhood characteristics to the individual home sales, we map each parcel into the 2010 Census block groups using the MetroGIS parcel data published by the Twin Cities Metropolitan Council in April of 2014. Missing neighborhood characteristics for the years 2006 through 2009 and 2011 through 2012 are linearly interpolated. Panel B of Table 1 reveals that the average Minneapolis home observed in our sample is located in a block group of around 1,075 residents, around 76% of whom consider themselves Caucasian, on average. These demographic characteristics, however, vary significantly during our sample. The smallest neighborhood, for example, records a total population of only 139 people, whereas the largest block group boasts around 3,500 residents.

Results

In this section, we present our primary findings. We begin with our discussion of the complaint-contour correlation and then turn towards our investigation of the noise complaint effect on residential property values. While the initial analysis is based on the entire annual grid-level sample across all seven Minnesota counties of the greater Twin Cities' metropolitan area, the subsequent hedonic analysis is centered on Minneapolis, for which we observe property transactions. Across all specifications, we report heteroscedasticity robust standard errors.

Noise Contour and Complaint Correlation

To answer the initial question of whether residential noise complaints are a reasonable measure of noise annoyance resulting from aircraft noise pollution, we begin by visualizing the raw correlations between noise complaints and contour noise at the grid level (Figure 2.1) and the Minneapolis property level (Figure 2.2). As suggested by the summary statistics presented in Panel A of Table 1, most of the 7,402 grids do not overlap with noise contours. Yet, many of these grids record positive noise complaints and are, thus, bunched at the zero lower bound shown in Figure 2.1. For those grids that (at least partially) fall within noise contour curves, however, we observe a slight rise in noise complaints as indicated by the upward sloping trend given in Figure 2.1.

[INSERT FIGURES 2.1 & 2.2 HERE]

At the property level, we face a similar challenge as most home sales fall outside the given contour curves. To overcome this issue, we calculate a rough prediction of contour noise levels for each transaction based on a simple regression that interacts a parcel's distance to the MSP international airport with annual fixed effects to approximate the geographic and temporal variation in aircraft noise pollution. Figure 2.2 presents a simple scatter plot of Minneapolis noise complaints against this predicted level of property-specific contour noise. The data provide strong evidence in support of a positive correlation between the traditional measure of aircraft noise pollution given by contour curves and residential noise annoyance captured via noise complaints.

To provide a benchmark of this complaint-contour-noise correlation, we estimate our initial model (Equation (1)) via OLS and present our findings in Table 2. Building from a parsimonious specification (Table 2, column (1)) to the full model as described by Equation (1) (Table 2, column (5)), we find that the correlation between grid-level contour noise and annual residential noise complaints ranges from 1.443 to 1.776 and is statistically significant at the 1% level across all specifications. The preferred model given in column (5) suggests that a one dB DNL increase in contour noise coincides with a 1.5 annual complaint increase. Grid population and the percentage of white residents also exert a statistically significant positive influence over annual noise complaints. The coefficient on the interaction between contour noise and abatement eligibility, however, is statistically indistinguishable from zero suggesting that an increase noise experienced by residents of abatement eligible properties does not lead to greater annual grid-level complaints.

[INSERT TABLE 2 HERE]

Recognizing the count characteristic and over dispersion of the MAC complaint data, we test and compare the fit of alternative count models against our baseline OLS estimation. Based on the AIC and BIC test statistics reported in in Table 7 in the Appendix, we find that the zero-inflated negative binomial estimator (ZINB) produces the best fit for our data. We present the preferred full model ZINB estimates based on Equation (1) in column (1) of Table 3. Controlling for year fixed effects, grid-specific population and ethnicity, and differentiating the correlation between noise complaints and noise pollution across soundproofing eligible and ineligible grids, we find that a one dB DNL increase in contour noise is associated with a rise in the expected log of noise complaints by 0.055. The coefficient estimate is statistically significant at the 1% level. Exponentiation of the coefficient produces a more meaningful interpretation and suggests that a one dB DNL increase in contour noise coincides with a 5.6% increase in the expected number of annual grid complaints. Similar to the OLS results, we find that increases in total population and the number of residents that identify as white also raise the expected number of complaints. Abatement eligibility does not alter the noise-complaint correlation.

The zero-inflation equation estimates are presented in Panel B of Table 3 and suggest that increases in grid population, indeed, reduce the probability of observing zero complaints. The more residents live in a grid, the more unlikely it becomes to observe no noise complaints. Similarly, the unreported coefficient estimates on the year fixed also suggest that the probability of zero annual grid complaints tends to fall over time. As the noise complaint program becomes more popular among local residents throughout time, it becomes less likely to observe no grid complaints. Lastly, the statistically significant parameter estimate for α supports our suspicion that the noise complaint data are, indeed, over dispersed.

Expanding upon these preferred ZINB findings in column (1), we also estimate the noise contour-complaint correlation with daytime (column (2) of Table 3) and nighttime complaints (column (3) of Table 3), respectively. Both estimations produce qualitatively and quantitatively similar results suggesting that both daytime and nighttime annual grid complaints rise with greater contour noise. In column (4), we restrict the sample to observations post 2014, after the conclusion of the abatement initiative. The coefficient estimate of interest falls to 0.027, but remains statistically significant at the 1% level. Lastly, we limit the sample to Minneapolis grids and find that a one dB DNL increase in contour noise coincides with a 3.9% increase the expected number of annual grid complaints, similar to our full sample estimate. Interestingly, this correlation, however, only holds for Minneapolis grids that are abatement ineligible. In contrast, we find that the complaint-contour correlation is significantly smaller for Minneapolis grids that contain abatement eligible properties. Our estimate (column (5) of Table 3) suggests that when all properties in a Minneapolis grid are sound proofing eligible a one dB DNL increase in contour noise coincides with a mere 1.6% rise in the expected number of annual grid complaints.

[INSERT TABLE 3 HERE]

Hedonic Complaint Effect Estimates

Overall, these estimates provide consistent evidence that residential noise complaints, and the reflected noise annoyance, are positively correlated with the traditional contour measure of aircraft noise pollution. Building on this finding, we expand our analysis to the hedonic model estimating the noise complaint effect on Minneapolis home sale prices and contrasting our results against the traditional contour-based measure.

To begin, we estimate the typical hedonic model and regress home sale prices on annual contour noise levels and a host of control variables commonly used in the literature. Similar to Friedt and Cohen (2019), our identification of the traditional aircraft noise pollution effect on home values is based on the differentiation of noise discounts across abatement eligible and ineligible properties. Friedt and Cohen (2019) provide a detailed discussion about the potential issues of reverse causality between home values and aircraft noise and argue that noise abatement provides a natural strategy to identify the causal relationship between these two variables. In short, if homeowners do not consider aircraft noise a disamenity, but instead reverse causality leads lower home values to cause greater aircraft noise pollution, than noise insulation should add no value to a home. Consequently, the interaction term between contour noise and abatement eligibility should be insignificant if aircraft noise is truly not a costly disamenity.[12] A positive abatement eligibility effect, however, speaks to the contrary and suggests that the causality runs from aircraft noise pollution to lower home values.

Consistent with this strategy and previous estimates (Friedt and Cohen, 2019), we find that aircraft noise pollution measured via noise contours causes a statistically and economically significant reduction in sale prices among Minneapolis homes located within these contour curves, while

[12] For a more detailed discussion of this identification strategy, see Friedt and Cohen (2019).

abatement eligibility offsets this noise discount. The coefficient estimates are presented in Table 4 and build from a parsimonious specification (column (1)) to the preferred model as described by Equation (2) (column (5)). While the parsimonious noise effect estimates (columns (1) through (3)) are large, they tend to decline with additional control variables, and the preferred parameter estimates presented in column (5) agree with much of the previous literature (see, for example, Boes and Nüesch (2011)). Specifically, we find that a one dB DNL noise increase reduces home values by 0.5% for abatement ineligible homes (column (5)). As expected, the number bedrooms, bathrooms, and fireplaces, as well as parcel's square footage exert a positive influence on sale prices. In contrast, newer homes tend to command lower values, which may be indicative of the fact older Minneapolis homes are located in more desirable neighborhoods near the MSP airport.

[INSERT TABLE 4 HERE]

Abatement eligibility offsets the adverse noise effect. In fact, we find that for every one dB DNL increase in contour noise, abatement eligibility reduces the noise discount by 0.1 percentage points. This aligns with the implementation of the noise abatement program, where the amount of sound insulation subsidies increased with greater aircraft noise pollution. Eligible homes at the 64 dB DNL, for example, received the full abatement package, valued around $30,000 to $40,000, while an eligible property experiencing 60 dB DNL according to the 2007 forecasted contour curves received a partial insulation package valued at around $14,000 (MAC, 2017). According to our coefficients, the former type of home experienced a full offset of the noise discount, while the latter was only partially reimbursed.

Overall, these estimates are generally consistent with the range of noise contour estimates from other hedonic airport noise studies, but face a major issue when it comes to out-of-sample, out-of-contour-plot predictions of the noise discounts. Since we cannot observe contour noise beyond the contour curves, the coefficients presented in Table 4 are based on a sample that is restricted to 3,644 Minneapolis homes sales located within the 2006 through 2017 MSP contour curves. Based on our estimates, a simple calculation comparing the observed sale price to the predicted counterfactual prices under zero contour-measured noise pollution suggests sustained economic aircraft noise damages of around $13.1 million. According to the MAC, abatement costs for the 2007 Consent Decree Program totaled $95 million pushing the total contour sample losses due to aircraft noise to around $108 million. Given that aircraft noise pollution, however, is continuous and does not go mute beyond the 60 dB DNL contour boundary, we believe that this represents a biased estimate of total economic losses ignoring the economic damages incurred by homeowners residing beyond the contour threshold.

To overcome this issue, we look to our Minneapolis complaint data to provide an alternative approach to measure the adverse effects of aircraft noise pollution in out-of-contour areas. Table 5 presents the estimation results for the effect of noise complaints on home values located outside and inside the MSP noise contour plots. To begin, we exclusively focus on the noise pollution effects outside of the contour region. Coefficient estimates shown in columns (1) through (3) develop the noise complaint effect from the parsimonious specification to the full model results and are based on the restricted out-of-contour sample. The preferred parameter estimates in column (3) tend to carry the expected signs and are statistically significant at the 1% level. Again, larger homes located in more populated neighborhoods command higher sale prices. Amenities, such as fireplaces, significantly increase home values. The coefficient estimate of interest shows that a 100% increase in local noise complaints lowers property values for non-contour Minneapolis homes by 0.5% (Table 5, column (3)).

As shown in column (4), this estimate is robust to the inclusion of cumulative past noise complaints. The significance of these results is that aircraft noise pollution causes home value discounts beyond the contour thresholds that are typically ignored by regulators.

[INSERT TABLE 5 HERE]

To provide further evidence in support of this finding, we expand our sample to include not only out-of-contour home sales, but also within contour transactions. Once again, the inclusion of these observations allows us to differentiate the noise pollution effect across abatement eligible and ineligible properties. The full sample complaint results presented in column (5) of Table 5 are consistent with the out-of-contour sample (see column (3)) and match those we obtain with the restrictive contour noise measure shown Table 4. A 100% increase in local noise complaints reduces sale prices by 0.5% for abatement ineligible homes, whereas homeowners of eligible properties experience a full offset in response to aircraft noise pollution increases.

In column (6), we investigate the persistence of this adverse complaint effect with respect to distance from the airport. To this end, we interact local noise complaints with a property's distance to MSP. As expected, properties in close proximity experience greater noise complaint discounts than houses located at greater distances from MSP. To visualize the spatial decay of the complaint discount, we plot the marginal effects of noise complaints on home values over distance to MSP (Figure 3). As one might expect, the noise complaint discount dwindles with distance and is approximately zero around 12 km from the airport – over twice the distance from the airport than the outer most contour of 60 dB DNL.

In order to compare the estimates from noise contours and noise complaints, we calculate the Mean Absolute Percentage Error (MAPE). The MAPE is a measure of forecasting accuracy when comparing different estimation processes. We use the MAPE to determine how well the hedonic model using each noise metric predicts the actual sales price. To draw this comparison, we restrict the sample to within-contour observations for which we have information on both complaints and noise contours. Using the noise contour estimates, the MAPE equals 1.46% (Table 4, column 5). On the other hand, the complaint estimates MAPE equals 1.56% (Table 5, column 6). While the MAPE for noise complaints is slightly higher than the MAPE for noise contours, the two differ by approximately 6%. Given that the noise complaints data cover a much broader range of properties than can be included in the noise contours, the 6% difference in MAPE is not large enough to select the noise contour approach over the complaints approach.

Finally, we use the noise complaint results reported in column (6) of Table 5 to determine the total losses incurred inside and outside of the MSP contours. Repeating the counterfactual calculations based on the complaint estimates, we find that total economic damages amount to $146 million, only $12 million of which fall within the contour curves. This within-contour estimates based on noise complaints is quite comparable to the $13.1 million based on contour noise. In contrast, $134 million, over 90% of total post abatement damages, are borne by homeowners residing outside of the MSP contours, who are ineligible for any abatement subsidies and do not experience harmful according to the FAA. This out-of-contour loss estimate is consistent with the Gillen and Levesque (1994) assertion that noise discounts based on noise contour data underestimate the true value of damages. Again, if we add in the $95 million in abatement costs already invested by the MAC over the past decade, we arrive at cumulative Minneapolis aircraft noise pollution damages of over $240 million. Still, we believe this is a conservative estimate of the true losses due to MSP aircraft noise pollution, as we are focusing solely on Minneapolis property transactions subject to around one third of all MSP complaints and only consider home sales from 2006 to 2017.

Given our finding that local noise complaints cause significant sale price discounts, we broaden our analysis and consider the effects on alternative housing market outcomes. Specifically, we consider the complaint effect on the number of sales per grid and per home, as well as the duration between sales for repeatedly sold properties. Table 6 details our findings with respect to each to these three outcome variables. At the grid level, we find that a 1% increase in local noise complaints raises the number of grid-specific home sales by 1.27 per year (Table 6, column (3)). Our findings suggests that along the extensive margin greater noise annoyance increases the supply of homes for sale. With respect to the intensive margin, we find that higher levels of noise complaints are also associated with an increase in the number of sales per home. A 100% increase in local noise complaints raises the number of sales by 0.3%, while abatement eligibility fully offsets this intensive margin effect (Table 6, column (6)). Lastly, we study the complaint effect on the duration between sales among the repeatedly sold homes. We find that rise in local noise complaints by 1000 filed reports increases duration between sales by around 2 month. This finding perhaps indicates that greater levels of residential noise annoyance make it more challenging to sell an affected home.

[INSERT TABLE 6 HERE]

Conclusion

The vast majority of airport noise studies in the previous literature have focused on how contour-based estimates of noise impact house prices. Some research has found that this can lead to under-estimates of the noise discount, for a variety of reasons. One of these is that the noise estimates may be inaccurate, and in some cases, missing below a certain threshold that the FAA does not classify as harmful (i.e., below 65 dB or in some cases 60 dB or 55 dB). Focusing on how complaints impact house prices can be a fruitful alternative.

In our analyses, we first demonstrate the strong positive correlation between observed noise levels and the probability of additional complaints. Next we demonstrate how additional complaints impact house prices near the Minneapolis/Saint Paul airport. We find the noise discounts from sales of properties beyond the noise contours to be plausible but at the same time significant. The estimates on the complaints variable imply noise discounts in the range of 0.5% for a 100% increase in residential noise annoyance. We estimate that over 90% of the resulting $146 million in economic damages fall outside of the contour area and are not generally picked up in other hedonic noise studies because beyond some lower noise threshold researchers typically assume the noise levels equal to zero.

There are significant policy implications of our findings. With the noise discount under-estimated in many outlying areas, perhaps additional soundproofing would be warranted. Another alternative might be for the federal government to encourage quieter aircraft. Altering flight paths to avoid some of these areas with greater complaints is another alternative, especially when there are undeveloped areas that could be candidates for rerouting during times of day when there are heavy complaints. Regardless, it seems as if the damages to society from aircraft noise are likely substantially higher than commonly perceived by airport authorities.

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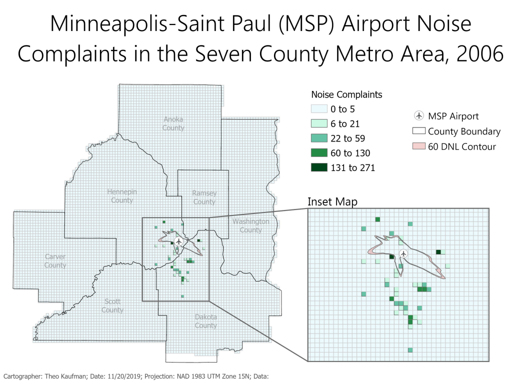
Appendix

[INSERT FIGURE 4 HERE]

[INSERT TABLE 7 HERE]

Tables and Figures



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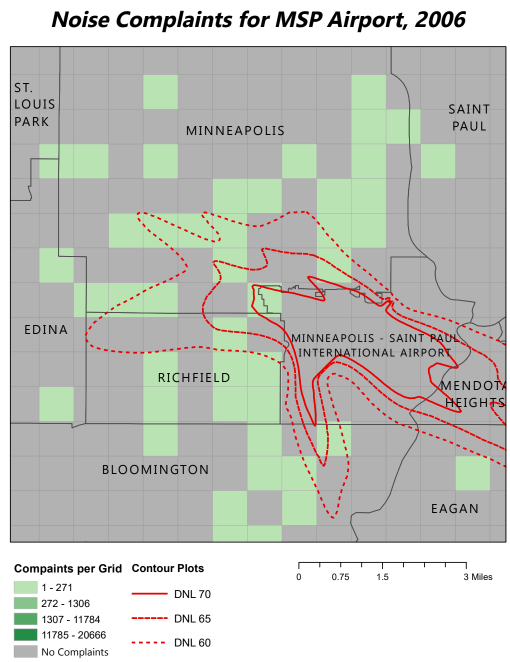

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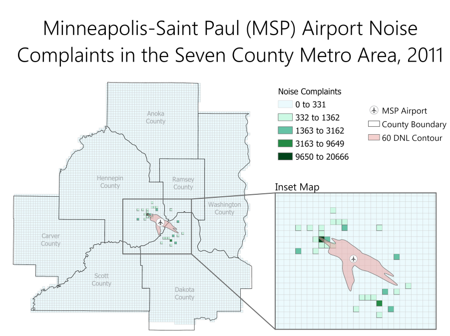

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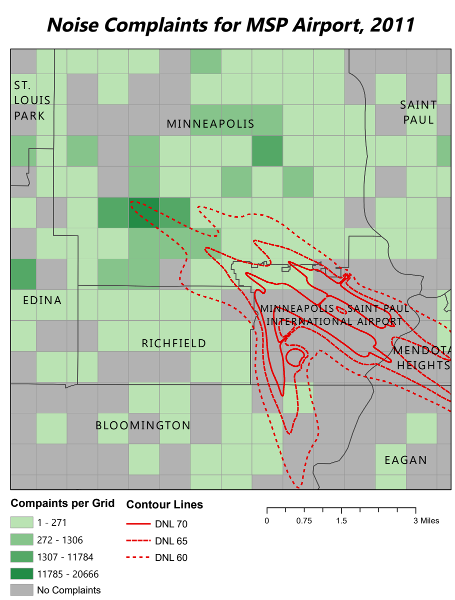

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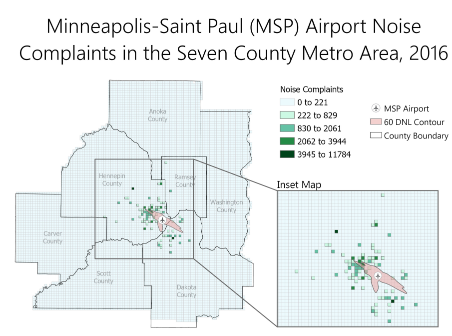

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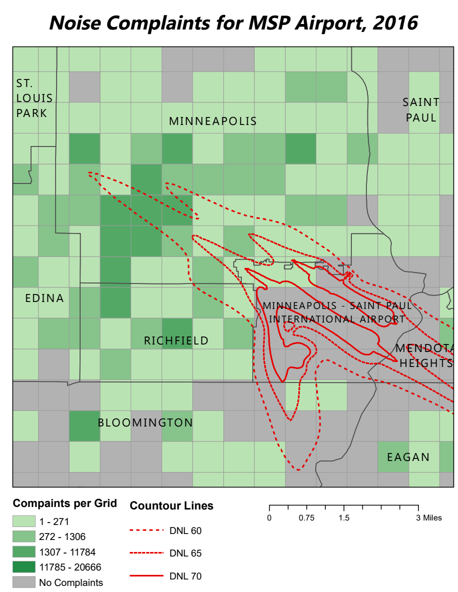


1.6: 2016

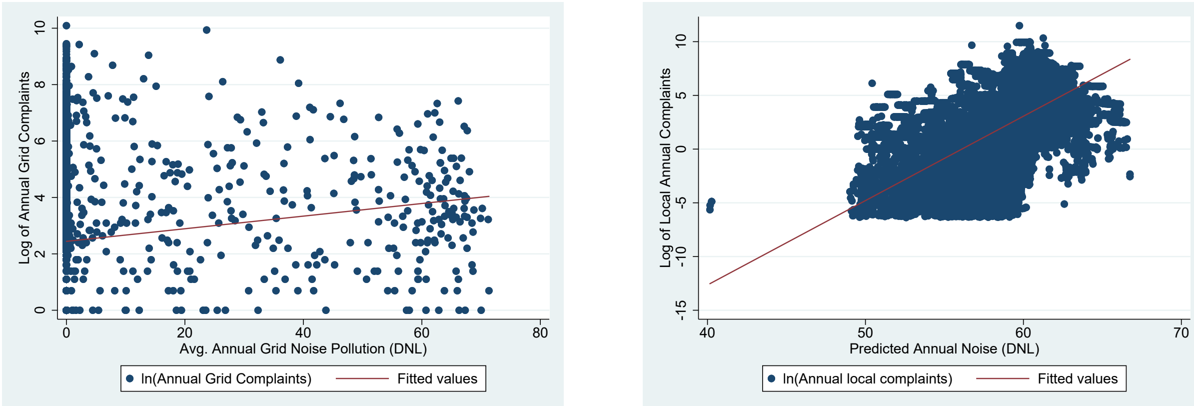
Figure 1: Minneapolis Noise Complaints relative to Noise Pollution for MSP

Table 1: Summary Statistics

	(1) Mean	(2) Median	(3) SD	(4) IQR	(5) Minimum	(6) Maximum	(7) Obs
Panel A: Grids							
Annual Complaints	10.46	0.00	214.64	0.00	0.00	24,130	88,824
Non-zero	190.69	8.00	897.42	53.00	1.00	24,130	4,874
Minneapolis	146.31	1.00	692.61	33.00	0.00	20,666	2,112
Annual Noise Pollution (DNL)	0.38	0.00	4.57	0.00	0.00	76	88,824
Complaint to Noise Ratio	420.11	0.00	6,364.18	1.47	0.00	164,033	895
Minneapolis Ratio	1,194.70	2.00	11,079.72	16.38	0.00	164,033	293
Annual # of Sales	23.50	19.00	20.98	26.00	0.00	168	2,112
Annual Grid Population	387.05	95.25	645.09	471.79	2.47	8,668	88,824
Annual Population, White (%)	90.42	94.59	10.86	8.74	10.67	100	88,824
Panel B: Minneapolis Homes							
Avg. Sale Price ($'000)	282.71	232.00	205.00	148.00	16.00	3,000.00	41,275
Avg. # of Sales	1.55	1.00	0.70	1.00	1.00	6	41,275
Dist.-Weighted Annual Local Complaints	300.89	16.42	1,063.69	168.22	0.00	97,962	41,275
Annual Grid Complaints	285.87	14.00	907.85	156.00	0.00	20,666	41,275
Annual Noise Pollution (DNL)	62.10	61.00	2.36	4.00	60.00	71	3,642
# of Bedrooms	2.87	3.00	1.18	2.00	0.00	15	41,275
# of Bathrooms	1.94	2.00	0.92	1.00	0.00	9	41,275
Year Built	1940	1928	32	39	1858	2017	41,275
Parcel Square Footage	18,105	5,719	38,973	3,048	467	315,895	41,275
# of Fireplaces	0.51	0.00	0.72	1.00	0.00	8	41,275
Distance to MSP Airport (km)	5.74	5.38	2.48	3.29	0.95	21	41,275
Annual BG Population	1,075	987	434	464	139	3,489	41,275
Annual Population, White (%)	75.89	83.14	20.43	22.77	0.00	100	41,275
Panel C: Minneapolis Repeat Sales							
Duration between Sales (Month)	59.64	57.00	32.21	50.00	1.00	142.00	9,883
Δ Local Complaints between Repeat Sales	279.91	3.09	1,530.58	194.02	-93,557	29,292	9,883

Panel A Notes: The statistics are based on a balanced sample of 7,402 distinct complaint grids generated by Metropolitan Airports Commission (MAC) and aggregated to an annual frequency from 2006 to 2017. Complaint and contour noise data are available through the MAC, whereas grid-level population and ethnicity statistics are derived from the 2010 U.S. Census and American Community Surveys 2013 through 2017. Minneapolis home sale data are available through the City of Minneapolis' Tax Assessment Office.

Panel B Notes: The statistics are based on a sample of 41,275 transactions of 32,433 unique Minneapolis homes. Home sale price information for 2006 through 2017 and the corresponding parcel characteristics data are sourced from the City of Minneapolis' Tax Assessment Office.



2.1: Grid Complaints & Avg. Grid Noise Pollution

2.2: Local Complaints & Predicted Noise Pollution

Figure 2: Annual Noise Complaints and Noise Pollution

Table 2: Noise Complaints and Pollution Correlations (OLS)

	(1)	(2)	(3)	(4)	(5)
Annual Noise Pollution (DNL)	1.751***	1.585***	1.443***	1.776***	1.496***
	(0.348)	(0.346)	(0.336)	(0.367)	(0.295)
Annual Grid Population ('000)			29.795***	42.299***	42.159***
			(2.317)	(3.768)	(3.692)
Annual Population, White (%)				1.134***	1.128***
				(0.165)	(0.161)
Noise $\times\delta_{gt}$					1.473
					(1.511)
Constant		6.416***	-4.286***	-111.793***	-111.045***
		(1.348)	(1.644)	(16.376)	(15.942)
Year FE	N	Y	Y	Y	Y
N	94,500	94,500	88,872	88,824	88,824
adj. R^2	0.00	0.00	0.01	0.01	0.01
F stat	25.26***	5.29***	16.58***	15.40***	14.46***

Notes: This table documents the correlation between grid-specific annual noise complaints and noise pollution using ordinary least squares (OLS). We estimate this correlation starting from a parsimonious specification (column (1)) to a fuller model controlling for overarching time trends (column (2)), as well as grid-specific characteristics, such as grid population (column (3)) and ethnicity (column (4)). In our preferred specification (column (5)) we additionally differentiate the correlation between noise complaints and noise pollution across soundproofing eligible and ineligible grids. All standard errors are heteroskedasticity robust. Statistical significance at the conventional 10%, 5%, and 1% significance levels is indicated via * ($p < 0.10$), ** ($p < 0.05$), *** ($p < 0.01$), respectively.

Table 3: Noise Complaints and Pollution Correlations (ZINB)

	(1)	(2)	(3)	(4)	(5)
Panel A: Main Equation					
Annual Noise Pollution (DNL)	0.055***	0.055***	0.071***	0.027***	0.039***
	(0.019)	(0.020)	(0.024)	(0.005)	(0.005)
Noise $\times\delta_{gt}$	0.026	0.023	0.023	-	-0.023***
	(0.037)	(0.037)	(0.043)		(0.008)
Annual Grid Population ('000)	0.521***	0.488***	0.503***	0.806***	0.001***
	(0.076)	(0.076)	(0.074)	(0.116)	(0.000)
Grid Population, White (%)	0.044***	0.043***	0.071***	0.086***	0.081***
	(0.007)	(0.007)	(0.005)	(0.008)	(0.005)
Constant	-0.655	-0.594	-5.204***	-4.025***	-5.020***
	(0.607)	(0.614)	(0.439)	(0.717)	(0.620)
Year FE	Y	Y	Y	Y	Y
Panel B: Inflation Equation					
Annual Grid Population ('000)	-5.250***	-5.103***	-4.138***	-5.235***	-0.003***
	(0.246)	(0.232)	(0.301)	(0.466)	(0.000)
Constant	3.810***	3.839***	4.071***	3.738***	1.543*
	(0.129)	(0.130)	(0.156)	(0.130)	(0.888)
Year FE	Y	Y	Y	Y	Y
N	88,824	88,824	88,824	22,206	2,124
Zeros	83,950	84,137	86,396	20,815	1,024
χ^2	134.92***	122.68***	455.20***	187.16***	652.84***
α	3.104***	3.114***	2.911***	3.027***	1.870***

Notes: This table documents the correlation between grid-specific annual noise complaints and noise pollution using the zero-inflated negative binomial estimator (ZINB). Given this estimator, the exponent of the reported coefficients yields the factor increase in noise complaints associated with a unit increase in the explanatory variable. Our preferred full-sample estimates are presented in column (1) and based on a full model specification that controls for overarching time trends via year fixed effects, as well as grid-specific characteristics, such as grid population, and ethnicity. Similar to Table 2, we differentiate the correlation between noise complaints and noise pollution across soundproofing eligible and ineligible grids. We test the sensitivity of our primary estimates against a number of sample restrictions, isolating the noise correlation with day-time (column (2)) and night-time complaints (column (3)), as well as post the abatement initiative (column (4)). Further, we limit the sample to Minneapolis grids (column (5)). All standard errors are heteroskedasticity robust. Statistical significance at the conventional 10%, 5%, and 1% significance levels is indicated via * ($p < 0.10$), ** ($p < 0.05$), *** ($p < 0.01$), respectively.

0.1 Noise Complaints and Home Sale Price Discounts

Table 4: Noise Pollution Effect on Home Values

	(1)	(2)	(3)	(4)	(5)
Noise pollution (DNL)	-0.031***	-0.036***	-0.021***	-0.005**	-0.005**
	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)
Noise pollution (DNL) $\times \delta_{it}$			0.003***	0.001***	0.001***
			(0.000)	(0.000)	(0.000)
# of Bedrooms				0.092***	0.092***
				(0.007)	(0.007)
# of Bathrooms				0.155***	0.149***
				(0.008)	(0.008)
# of Fireplaces				0.144***	0.137***
				(0.006)	(0.006)
Year Built				-0.007***	-0.007***
				(0.001)	(0.001)
ln(Parcel Square footage)				0.184***	0.184***
				(0.025)	(0.025)
ln(BG population)					0.032**
					(0.015)
BG population, white (%)					0.004***
					(0.000)
Constant	14.546***	14.994***	14.092***	25.243***	24.006***
	(0.150)	(0.157)	(0.189)	(0.936)	(0.951)
Month FE	N	Y	Y	Y	Y
Year FE	N	Y	Y	Y	Y
N	3,657	3,657	3,657	3,644	3,644
adj. R^2	0.03	0.07	0.09	0.60	0.61
F stat	167.33***	15.27***	19.83***	149.87***	150.31***

Notes: This table presents the effect of noise pollution on home values. Across all specifications the sample is restricted to Minneapolis home sales within MSP noise contour plots from 2006 to 2017. We estimate the noise pollution effect starting from the parsimonious model (column (1)) to a fuller model controlling for seasonality and overarching time trends (column (2)), as well as abatement eligibility under the Consent Decree program (column (3)), and other house- (column (4)) and neighborhood-specific characteristics (column (5)), such as the # of bedrooms or block group population. All standard errors are heteroskedasdicity robust. Statistical significance at the conventional 10%, 5%, and 1% significance levels is indicated via * ($p < 0.10$), ** ($p < 0.05$), *** ($p < 0.01$), respectively.

Table 5: Complaint Effect on Home Values

	(1)	(2)	(3)	(4)	(5)	(6)
ln(Local Complaints)	-0.002**	-0.003***	-0.005***	-0.006***	-0.005***	-0.009***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
ln(Local Complaints) $\times \delta_{it}$					0.015***	0.016***
					(0.001)	(0.001)
ln(Cumulative complaints)				0.002		
				(0.001)		
ln(Local Complaints) $\times$						0.001***
Distance to MSP (km)						(0.000)
# of Bedrooms		0.070***	0.074***	0.074***	0.075***	0.075***
		(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
# of Bathrooms		0.198***	0.195***	0.195***	0.193***	0.193***
		(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
# of Fireplaces		0.184***	0.177***	0.177***	0.173***	0.173***
		(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Year Built		-0.001***	-0.000***	-0.000***	-0.001***	-0.001***
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ln(Parcel sq. ft.)		-0.007**	-0.009***	-0.009***	-0.006*	-0.006*
		(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
ln(BG Population)			0.027***	0.028***	0.026***	0.027***
			(0.006)	(0.006)	(0.006)	(0.006)
BG Pop., white (%)			0.004***	0.004***	0.004***	0.004***
			(0.000)	(0.000)	(0.000)	(0.000)
Constant	13.008***	13.283***	12.745***	12.745***	12.979***	12.984***
	(0.017)	(0.156)	(0.166)	(0.166)	(0.161)	(0.161)
Month FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Community FE	Y	Y	Y	Y	Y	Y
N	37,709	37,633	37,633	37,633	41,275	41,275
adj. R^2	0.35	0.64	0.64	0.64	0.64	0.64
F stat	636.36***	1241.33***	1236.47***	1206.38***	1331.39***	1300.96***

Notes: This table presents the effect of noise complaints on home values. Across the first four specifications the sample is restricted to Minneapolis home sales outside of the MSP noise contour plots. The last two specifications include the full sample of Minneapolis home sales from 2006 to 2017. We estimate the noise complaint effect starting from the parsimonious model including year, month, and community fixed effects (column (1)) to a fuller model controlling house- (column (2)) and neighborhood-specific characteristics (column (3)). In column (4), we additionally control for cumulative past noise complaints, whereas results in column (5) are based on an extended sample including all Minneapolis home sales and therefore differentiate the complaint effect across abatement eligible and ineligible properties. For the preferred specification, given in column (6), we also interact the noise complaint effect with distance from the MSP international airport. All standard errors are heteroskedasdicity robust. Statistical significance at the conventional 10%, 5%, and 1% significance levels is indicated via * ($p < 0.10$), ** ($p < 0.05$), *** ($p < 0.01$), respectively.

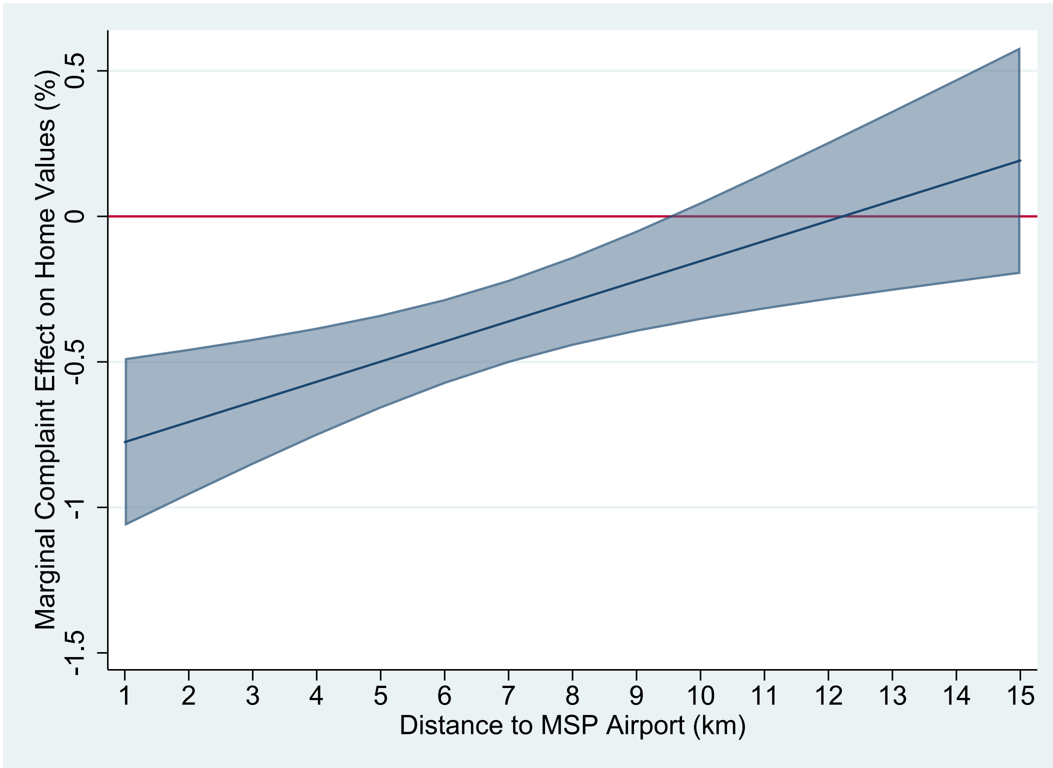


Figure 3: Marginal Noise Complaint Effect on Home Values over Distance from MSP

Table 6: Complaint Effect on the # of Sales and Duration Between Repeat Sales

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dependent Variable	# of Sales per Grid per Year			# of Sales per Home			Month between Repeat Sales		
ln(Local Complaints)	1.096***	1.523***	1.265***	0.001	0.005***	0.003**			
	(0.134)	(0.137)	(0.161)	(0.001)	(0.001)	(0.002)			
ln(Local Complaints) $\times \delta_{it}$		-0.255	0.882*		-0.003	-0.005***			
		(0.469)	(0.501)		(0.002)	(0.002)			
Δ Local complaints between repeat sales							0.002***	0.001***	0.001***
							(0.001)	(0.000)	(0.000)
Δ Local complaints $\times \delta_{it}$								0.001**	0.001**
								(0.000)	(0.001)
House Characteristics	N	Y	Y	N	Y	Y	N	Y	Y
Neighborhood Controls	N	Y	Y	N	Y	Y	N	Y	Y
Month FE	N	N	N	N	N	N	N	Y	Y
Year FE	N	Y	Y	N	N	N	N	Y	Y
Community FE	N	N	Y	N	N	Y	N	N	Y
Unit of observation	Grid-Year			House			House-Year-Month		
N	1,806	1,806	1,806	38,005	37,658	37,658	11,599	11,552	11,552
adj. R^2	0.04	0.17	0.34	0.00	0.02	0.02	0.01	0.22	0.23
F stat	67.35***	34.33***	28.45***	1.27	71.43***	38.68***	11.67***	616.91***	419.42***

Notes: This table presents the effect of noise complaints on the number of home sales per grid per year (columns (1)-(3)), the number of sales per home (columns (4)-(6)), and the duration between repeat sales (columns (7)-(9)). For each of these outcome variables, we estimate the three noise complaint effects starting from the parsimonious model (columns (1), (4), and (7)) to a fuller model controlling house- and neighborhood characteristics, as well as time fixed effects when appropriate (columns (2), (5), and (8)). The preferred specifications are given in columns (3), (6), and (9) and additionally include community fixed effects. All standard errors are heteroskedasdicity robust. Statistical significance at the conventional 10%, 5%, and 1% significance levels is indicated via * ($p < 0.10$), ** ($p < 0.05$), *** ($p < 0.01$), respectively.

A Appendix

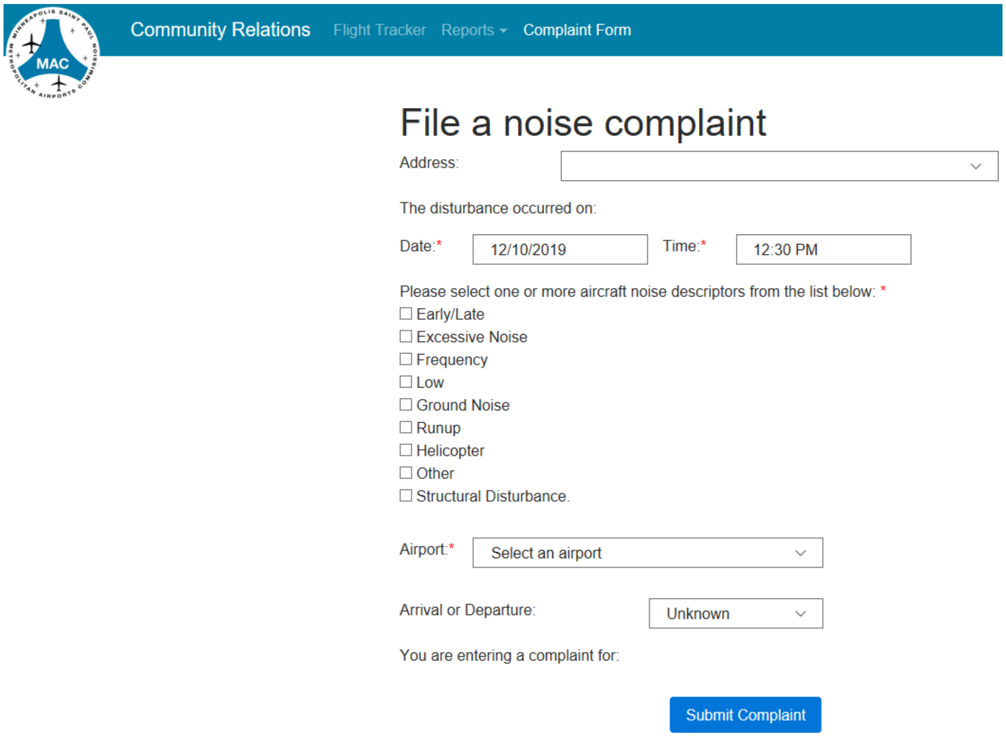


Figure 4: Noise Complaint Template

Table 7: Model Comparison

	(1) # of Observations	(2) Log- Likelihood	(3) Degrees of Freedom	(4) AIC	(5) BIC
OLS	88,824	-602,416	16	1,204,864	1,205,014
PRM	88,824	-4,034,695	16	8,069,423	8,069,573
NBRM	88,824	-3,9531.04	17	79,096.07	79,255.78
ZINB	88,824	-36,096.16	30	72,252.31	72,534.15

Notes: This table presents a model comparison between the ordinary least squares (OLS) estimator and the three count models, including the Poisson (PRM), Negative Binomial (NBRM) and Zero-Inflated Negative Binomial (ZINB) estimators. The relevant statistics include the log-likelihood, the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC) and are based on the full model specification presented in column (5) of Table 2. For the calculation of BIC we assume that N equals the number of observations. The conclusions of the model comparison hold if we assume N equals the number of clusters (7402 grids) instead.