The Nature of Noise Complainers and Housing Price Effects around MSP: An IV Approach.

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Abstract: Aircraft noise pollution adversely affects physical and mental health and often is borne by disadvantaged residents. Previous research quantified these problematic effects through the losses that are capitalized into home values and relied heavily on noise contour plots to identify these house price discounts. Contour plots offer geographically limited insights on aircraft noise pollution and do not capture property value decreases beyond the contour boundaries. In this study, we overcome this limitation by leveraging a dataset of over 700,000 noise complaints surrounding the Minneapolis-St. Paul International Airport from 2010 through 2017. First, we uncover the nature of noise complainers by mapping observed noise complaints against neighborhood socioeconomic and demographic characteristics. We find noise complainers are likely more affluent and educated. However, conditional on income and education, we also find complaints to rise in more populated neighborhoods with fewer white residents. Second, a major finding is that using the IV approach instead of a least squares approach leads to lower elasticity estimates - specifically, in the range of -0.007 to -0.011, instead of -0.015 with the least squares approach. Ignoring the endogeneity of complaints can over-state the harm being borne by homeowners as measured through their home sales prices.

JEL Codes: R2, R3, Q53

Keywords: Airport Noise, Noise Pollution, House Prices, Instrumental Variable

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1 Introduction

Aircraft noise is among the most detrimental environmental effects of aviation. Research has shown it can cause annoyance among local residents and disrupt their sleep. It adversely affects academic performance of children and there is some evidence it may increase the risk for cardiovascular disease of people living in the vicinity of airports (Basner et al. 2017) [2]. Because of these adverse effects, the International Civil Aviation Organization argues that "aircraft noise is the most significant cause of adverse community reaction related to the operation and expansion of airports" and that this issue"is expected to remain the case in most regions of the world for the foreseeable future" (ICAO, 2022). These adverse effects are capitalized in property values; and, in this study, we investigate the causal effects of aircraft noise pollution on home sale prices surrounding the Minneapolis-St. Paul International Airport (MSP) from 2010 through 2017.

There is, of course, a well established body of literature studying these effects in multiple contexts[1]. However, the property-value-noise-pollution relationship is subject to endogeneity and the estimation of the causal effect of aircraft noise pollution on home values requires a solid identification strategy (see, for example, Boes and Nüesch (2011) [3], Affuso et al. (2019) [1], or Friedt and Cohen (2021) [6]). Moreover, much of this research has relied on geographically limited contour plots to measure aircraft noise pollution and is therefore constraint to studying home sale price discounts in close proximity to the respective airports. In fact, in the contest of MSP, Friedt and Cohen (2021) [5] have shown that these home sale price discounts extent roughly twice as far from the airport as suggested by contour plots. In this study, we address both concerns.

To overcome the latter issue, we follow Friedt and Cohen (2021) [5] and rely on residential noise complaints to measure aircraft noise pollution. While geographically less restrictive than contour plots, noise complaints may be endogenous to the determination of property

[1]See, for example, Cohen and Coughlin (2008) [4] or Affuso et al. (2019) [1] for analysis of varying geographies, or Friedt and Cohen (2021) [6] and Boes and Nüesch (2011) [3] for a contrast between single family homes and rental apartment.

sale prices due to unobservable socioeconomic characteristics of the noise complainer, which also influence home values. To overcome this endogeneity concern and identify the causal effect of aircraft noise pollution on house sale prices we take a two-pronged approach. First, we construct a novel dataset that links Minneapolis noise complaints with a host of observable socioeconomic census-tract characteristics. Detailing and controlling for the likely nature of complaining residents limits the potential omitted variable bias stemming from confounding determinants of house sale prices that are also correlated with the residents' propensity to complain. Second, we employ an instrumental variable's (IV) approach to address the issue of unobservable characteristics that continue to plague the hedonic model.

Our proposed IV are hourly MSP airport operation counts from 2010 through 2017. We link these operation counts to a large dataset of over 700,000 residential noise complaints collected by the Metropolitan Airport Commission (MAC), which operates the MSP airport. As part of the complaint program, residents in the seven counties[2] surrounding MSP can register a complaint on-line or over the phone at any time and must link their complaint to an aircraft noise event (see Figure 5 in the Appendix). While residents disclose their own location, the airport authority maintains anonymity of complainers by reporting noise complaints over a pre-specified 0.5 mile by 0.5 mile grid. Importantly for our identification strategy, MAC reports the precise timing of each complaint so that we can link hourly grid level complaints between 2010 to 2017 to annual operation counts by the hour of the day. This shared timing correlates aircraft operations and noise complaints, but is arguably exogenous to the determination of house sale prices.

Following our proposed methodology, we first estimate the first-stage noise complaint equation. The analysis provides evidence in support of the relevance of our proposed instrument and reveals a number of expected and a few interesting patterns regarding the likely nature of noise complainers. Specifically, we find that a 10% increase in hourly MSP operations is associated with around 100 additional hourly complaints per grid per year.

[2]These include Anoka, Carver, Dakota, Ramsey, Washington, Scott, and Hennepin county.

With respect to the socioeconomic control variables we observe that increases in income and grid population raise the number of grid-level complaints, whereas the age and birthplace of these residents does not seem to be a good predictor of complaint behavior. In contrast there is some evidence to suggest that complaints rise with education and tenure of local residents as well as the share of residents that work from home. Interestingly, we find that, conditional on these other socioeconomic characteristics, neighborhoods with greater shares of white residents register fewer complaints. This suggests that at a given level of income and education, for example, non-white residents are more likely to complain and therefore more likely to be exposed to aircraft noise pollution.

In the second stage, we estimate the hedonic house sale price model using the prediction of noise complaints from the first-stage regression. Among several interesting findings, the results clearly demonstrate (1) that aircraft noise pollution measured via noise complaints has a statistically and economically significant effect on home sale prices; and (2) that the issue of endogeneity is present when relying on noise complaints. As to (1), the primary findings indicate that a 10% rise in noise complaints reduces house sale prices by nearly 0.1%. To put these estimates into context, it is important to consider the fact that noise complaints are heavily concentrated around the airport. Among locations with non-zero noise complaints, a property located in grid with the median level of complaints will experience a sale price discount of around 2.9% relative to a similar home located in a grid with zero noise complaints. For those homes located in grids at the 90th percentile of noise complaints, the sale price discount increases to around 7%. This suggests that some property's are subject to significant aircraft noise pollution and that the owners of these homes experience considerable price discounts when selling their properties.

As to (2), we find endogeneity is a concern. We find that relying on actual noise complaints (rather than predicted noise complaints) leads to a notable increase in the estimate sale price discount. In other words, failure to instrument for noise complaints inflates the estimate of the causal impact of aircraft noise pollution on home sale prices by around 50%.

The remainder to this paper is organized as follows. In section 2, we review the relevant literature. In section 3, we develop our two stage empirical approach before summarizing the data and discussing the validity of our instrumental variable in section 4. First-stage and second-stage results are reported in section 5 and we conclude in section 6.

2 Literature Review

TBD ...

This literature traditionally relies on the hedonic approach to estimate the effect of aircraft noise pollution on home sale prices. Under this framework, house sale prices are modelled as a function of various home characteristics, such as the number of bedrooms, and neighborhood attributes, such as density or residential demographics, as well as other amenities and/or disamenities.

One such characteristic is aircraft noise pollution and has been shown to cause significant home price discounts (Friedt and Cohen (2021) [5]; Friedt and Cohen (2021) [6]). Traditionally noise pollution is measured via noise contours, which are determined via a mathematical model taking various inputs into account. Each contour represents an average noise pollution exposure of residents located around the airport dissipating with distance. Contour thresholds (i.e. 60 dB DNL), beyond which aircraft noise pollution is deemed insignificant, are federally regulated and geographically restricted. While it is clear that noise pollution does not go mute outside the contour thresholds, researchers tend to have little information regarding the intensity of aircraft noise pollution beyond these boundaries. As a result most of the research has focused on the dis-amenity effects near the airport where contour-based measurements of noise pollution are available.

TBD ...

3 Approach

In the context of MSP, the airport authority not only publishes contour plots, but has also collected over 1,000,000 residential noise complaints. Noise complainers can register a complaint on-line or over the phone at any time and must link their complaint to an actual noise event and disclose their own location. Since noise complaints are not bound by contour boundaries, these statistics may offer important insights on residential experience of aircraft noise pollution and the resulting home price discounts beyond regulated contour thresholds.

While the noise complaints are likely correlated with aircraft noise pollution and have been used in the hedonic framework to estimate house sale price discounts (see, for example, Friedt & Cohen (2021) [5]), it is important to recognize that unobserved characteristics of the complaining resident may also be correlated with home values. These correlations - when unobserved and/or uncontrolled for - can bias the hedonic estimates. If more affluent residents living in more expensive homes, for example, are also more likely to complain, a hedonic regression analysis that fails to control for residential income produces a positive bias that attenuates the estimated sale price discount.

We address this issue in two ways. First, we control for a host of socioeconomic characteristics of the neighborhoods surrounding each anonymous noise complainer. Detailing and controlling for the likely nature of complaining residents limits the potential omitted variable bias stemming from confounding determinants of house sale prices that are also correlated with the residents' propensity to complain. Nonetheless, there may be other unobservable characteristics that continue to plague the hedonic model. To address this issue, the second part of our identification strategy rests on the instrumental variable's (IV) approach. Under this methodology, one performs two regression analyses. In the first-stage, one regresses the potentially endogenous explanatory variable on a set of exogenous control variables common to both estimations and one instrumental variable excluded from the second stage regression. One then forms a prediction of the endogenous explanatory variable based on the first-stage estimates and feeds this prediction into the second-stage model. In our context, the first-stage regression models noise complaints as a function of various socioeconomic and housing neighborhood characteristics as well as hourly MSP airport operation counts - the proposed IV. We use these estimates to predict noise complaints. In the second stage, we estimate the standard hedonic model of house sale prices as a function of home characteristics, the same neighborhood attributes, and the predicted noise complaints.

Of course, the validity of this approach hinges on the IV satisfying the well known relevance and exclusion criteria. In our context, these conditions prescribe that we must identify an IV that is correlated with noise pollution captured in noise complaints (relevance), but is otherwise uncorrelated with home sale prices (exclusion). Our proposed IV is an annual count of MSP aircraft operations by hour of the day which is closely linked to hourly complaint counts. We discuss the validity of this IV in the next section.

The resulting estimation model can be described as follows:

$$\text{First Stage:} \qquad C_{gyh} = \beta_0 + \beta_1 Z_{yh} + \gamma X_{gy} + \alpha_j + \alpha_y + \nu_{gyh}; \qquad (1)$$

$$\text{Second Stage:} \qquad ln(SP_{it}) = \delta_0 + \delta_1 ln(\hat{C_{gy}}) + \lambda H_i + \zeta X_{ly} + \alpha_c + \alpha_y + \alpha_m + \epsilon_{it}. \qquad (2)$$

In the first stage, C_{gyh} represents annual (y) complaint counts by hour (h) of the day. These complaint counts are recorded at the grid (g) level[3] spanning seven counties surrounding the MSP airport (see Figures 1a and 1b). X_{gy} represent the aforementioned socioeconomic, demographic, and housing market controls, while α_j and α_y represent county (j) and year fixed effects. Z_{yh} represents the IV which is given by log of annual MSP operation counts by hour of the day. Based on the first-stage estimates we predict annual hourly complaints by grid and aggregated these predictions to the annual-grid level.

In the second stage, $ln(SP_{it})$ represents the natural log of house i's sale price at time t and is modeled as a function of time-invariant home characteristics (H_i), annual census-tract (l) attributes (X_{ly}) that include the same socioeconomic, demographic, and housing market

[3]Grids are 0.5 miles by 0.5 miles in size.

controls as in the first stage, and multiple fixed effects (community c, year y, and month m).[4] The variable of interest is given by predicted annual grid-level complaints ($\hat{C_{gy}}$).

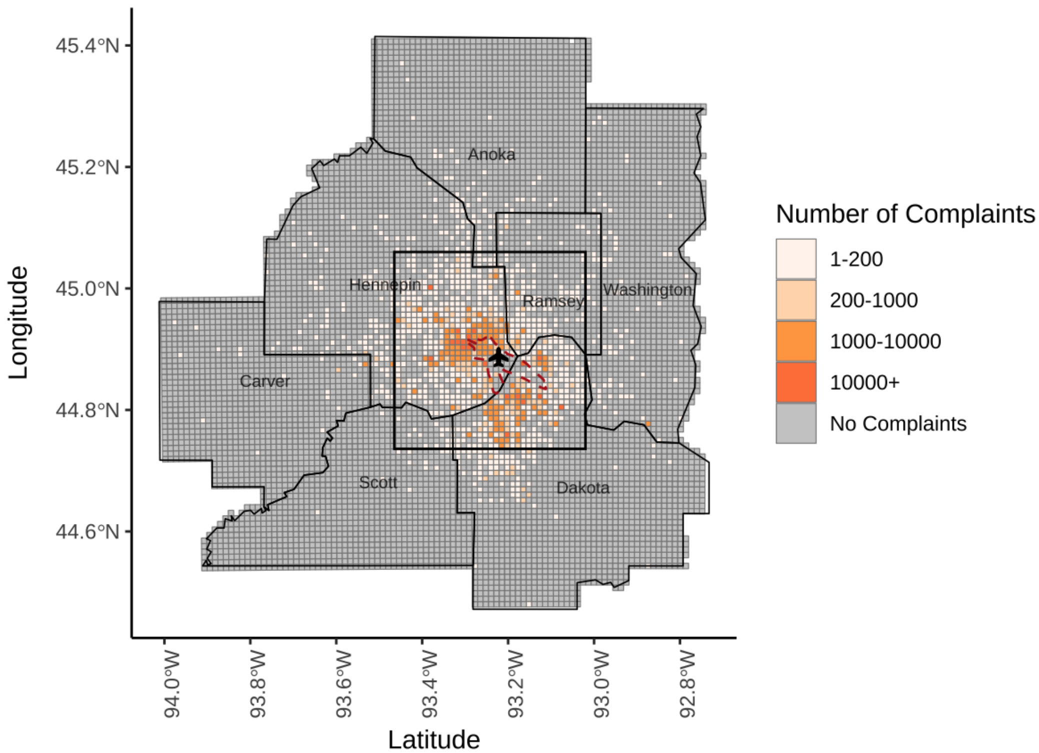
This two-step approach strengthens the identification of the causal effect of aircraft noise pollution, measured via residential noise complaints, on home prices and provides novel insights into the nature of noise complainers near the MSP airport.

4 Data

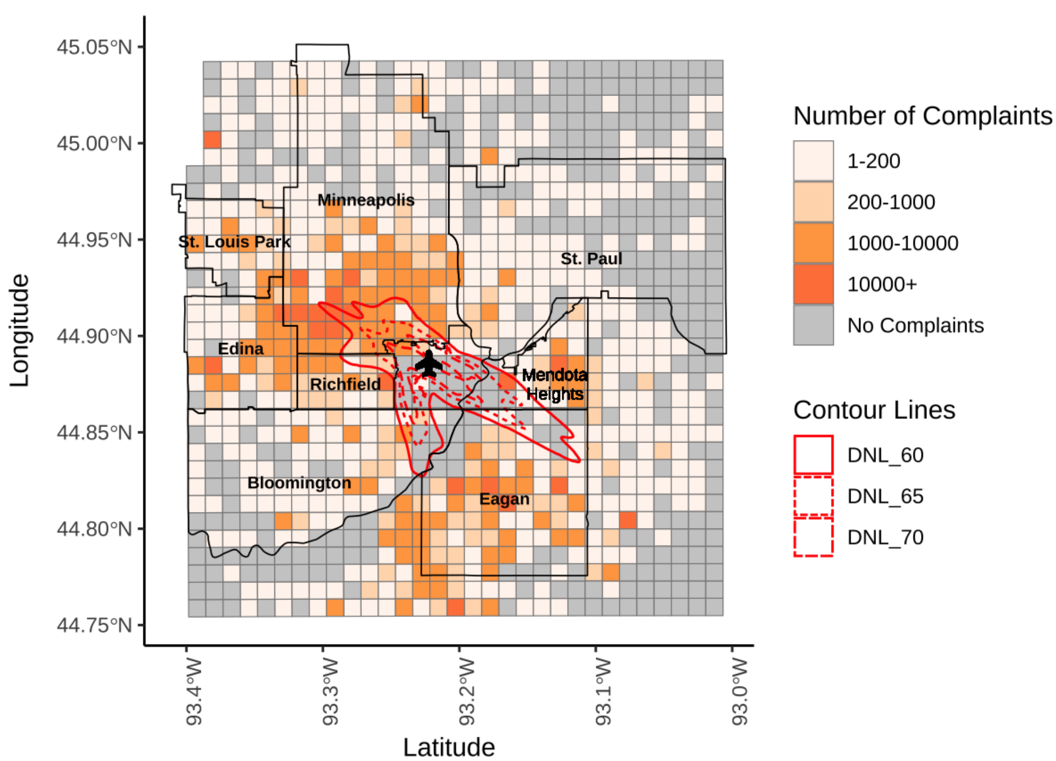
To estimate this two-stage model, we combine multiple variables from several sources and construct two novel datasets aggregating information at the grid and property levels, respectively. Information on noise complaints, contour curves, and MSP airport operations were generously provided by the Metropolitan Airports Commission (MAC). Noise complaints are precisely recorded at the time of the complaint. While complainers remain anonymous (the exact location is unknown), complaints are recorded at a pre-specified grid level. Figures 1a and 1b map total grid level complaints between 2010 and 2017 across the seven counties surrounding MSP. The figures demonstrate three key facts. First, MAC has registered numerous complaints over our sample period. Between 2010 and 2017, a total of 707,584 complaints were recorded. Second, most complaints occur near the airport, especially in the South Minneapolis, Richfield and Edina neighborhoods. Local residents seem to dislike aircraft noise albeit the fact that they have chosen to locate near the airport. Third, while most complainers are located near the MSP airport, the vast majority of complaints (over 80%) occur outside of the contour boundaries.[5] From these maps it is clear that noise contours are an imperfect measure of the resident's experience of aircraft noise pollution and likely underestimate residential noise annoyance.

[4]We include year and month fixed effects to control for common economic trends and seasonality in the Minneapolis housing market.

[5]For the ease of exposition, Figure 1b maps the total number of grid-level complaints between 2010 and 2017 relative to 2017 contours. While contours change from year to year as shown in Figures 4a-4h in the Appendix, the fact that the majority of complaints fall outside contour boundaries remains unchanged. Table 5 shows that for all years (except for 2011) over 80% of complaints are recorded in grids beyond the



(a) Seven Minnesota counties surrounding MSP



(b) Minneapolis surrounding areas

Figure 1: 2010-2017 Noise complaints relative to 2017 noise contours surrounding MSP.

Panel A of Table 1 summarizes these grid-level complaints and shows that on average 11 annual complaints are registered per grid from 2010 to 2017. However, as Figure 1a shows complaints are concentrated and complaints average over 200 per year for those grids with at least one complaint during our sample period. Interestingly, more grids report night time complaints, while complaints during the day are more intense among grids where such complaints are registered.

To construct the grid-level dataset, we aggregate grid-level complaints by year and hour of the day they were recorded. We merge this information with operations statistics, which reveal the annual number of aircraft operations at the MSP airport by hour of the day. This key variable represents our instrumental variable and must satisfy the aforementioned relevance and exclusion criteria. As to the relevance condition, it is clear that the number of aircraft operations (i.e. arrivals and departures) are directly related to the aircraft noise pollution stemming from the MSP airport. Residents officially complaining about this noise pollution must link their complaint to an aircraft operation in order to register it with the MAC. As part of their complaint residents must identify their address, the date and time of the noise event, select from a list of aircraft noise descriptors, identify whether the aircraft operation was a departure or arrival, and which airport it was associated with (if possible). Figure 5 in the Appendix shows the on-line MAC complaint form residents must complete. Because of this specific feature, the timing of aircraft operations should be positively correlated with timing of noise complaints. Figure 2 plots the log of complaints and MSP aircraft operation counts by hour of the day for each of our sample years. Figure 2 clearly illustrates the expected correlation. Over the eight-year sample period, hourly complaints rise and fall with aircraft operations during those times of the day.

As to the exclusion condition, we note that the key identifying variation in the first stage is the joint hourly timing of aircraft operations and subsequent noise complaints. This timing of operations throughout a given day has arguably no influence on house sale prices.

60 dB DNL boundary.

Table 1: Summary Statistics

	(1) Mean	(2) Median	(3) SD	(4) Min	(5) Max	(6) Obs
Panel A: Grids						
Total Complaints ('000)	0.011	0.000	0.230	0.000	24.130	63,000
Non-zero	0.217	0.009	0.990	0.001	24.130	3,254
Night Complaints ('000)	0.001	0.000	0.020	0.000	3.889	63,000
Non-zero	0.029	0.004	0.125	0.001	3.889	3,133
Day Complaints ('000)	0.010	0.000	0.216	0.000	22.470	63,000
Non-zero	0.211	0.008	0.947	0.001	22.470	1,604
Panel B: Minneapolis Homes						
Average Sale Price ($'000)	268.500	228.500	152.379	64.025	1102.500	52,176
Number of bathrooms	1.913	2.000	0.870	0.000	12.000	51,781
Number of bedrooms	2.896	3.000	1.239	0.000	15.000	51,781
Number of fireplaces	0.479	0.000	0.695	0.000	5.000	51,781
Year the house was built in	1941	1929	32.521	1858	2017	51,773
Distance ('000)	9.315	8.769	4.301	1.425	34.943	52,176
Actual Complaints ('000)	1.338	0.206	2.704	0.000	25.737	34,149
Predicted Complaints ('000)	0.795	0.027	1.410	-0.601	7.406	52,176

Panel A Notes: The statistics are based on a sample of 7,406 distinct complaint grids generated by Metropolitan Airports Commission (MAC) and aggregated to an annual frequency from 2010 to 2017.

Panel B Notes: The statistics are based on a sample of 52,176 sales, which exclude top 1% and bottom 1% sale prices. The complaints reported are the total number of the complaints in the year of the sale.

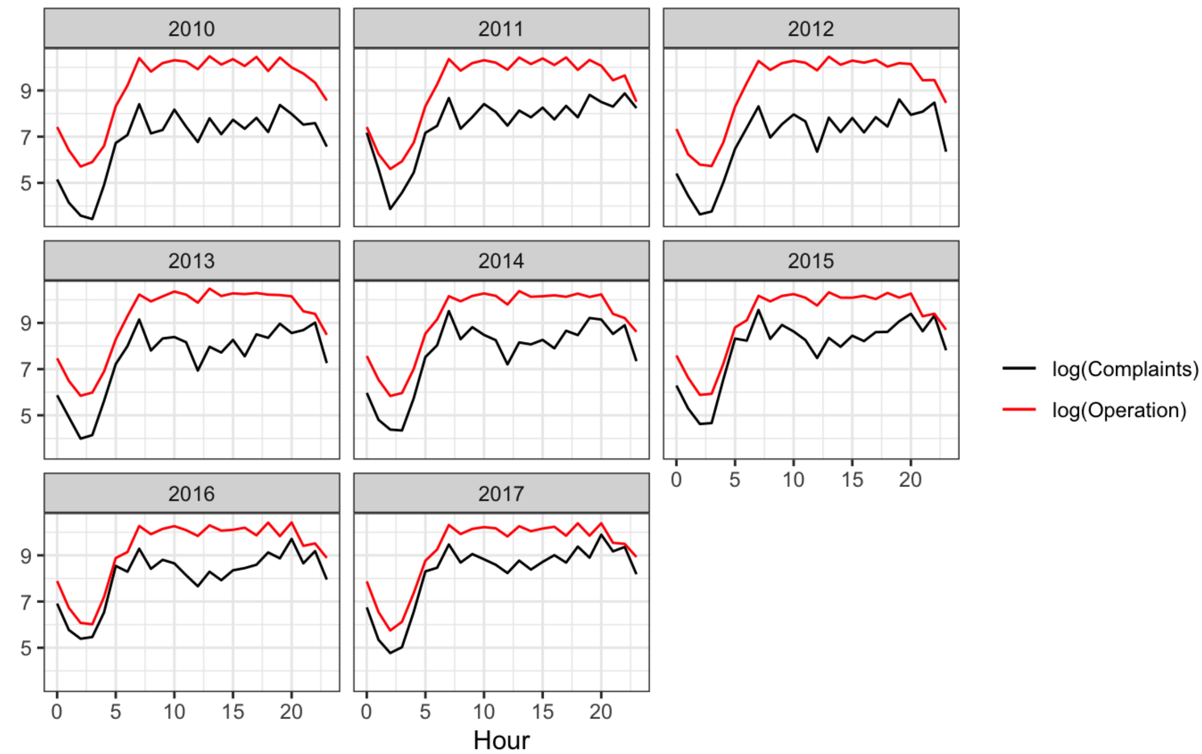


Figure 2: Hourly Complaints vs. Hourly MSP Aircraft Operations by Year

Moreover, we argue that annual MSP aircraft operations do not influence house sale prices aside from the aircraft noise pollution created by these operations. Of course, this noise pollution is precisely what is identified and controlled for through noise complaints and there is no other channel through which aircraft operations should impact house sale prices.

We complete the grid-level dataset used in the first-stage regression with numerous socioeconomic and demographic neighborhood attributes as well as local housing market characteristics. These data are sourced from the American Community Survey (ACS) published by the US Census Bureau.[6] Between 2010 and 2017, the data are available at the census tract level and observed with annual frequency.

Because census tracts do not align with noise complaint grids, we are forced to derive grid-level characteristics from the census tract information. To do so, we first determine the areas of each census tract that overlap with a given complaint grid. With these grid-

[6]For further details on exact sample size, data quality measures, and methodology, we refer the readers to the American Community Survey website in the Technical Documentation and Methodology sections.

census-tract shares in hand, we then estimate grid-level population and other characteristics assuming that the census tract population is uniformly distributed within the census tract. That is, if an entire grid covers 50% of the area of a census tract, we estimate this grid's population at 50% of the specific census tract's population. If one grid intersects multiple census tracts, we first calculate grid population as described for each overlapping area and then sum across the entire grid. Various grid-level population shares (i.e. % of population that is white) are calculated in a similar fashion, while grid-level medians represent the weighted average of the intersecting census tract medians.

Table 2 provides summary statistics for each of the converted grid-specific census characteristics. We categorize our variables into three major groups including demographic characteristics, economic and employment-related determinants, and housing market attributes. Table 2 shows the average grid is home to around 162 residents at an average age of around 40, 90% of whom are white, with a median household income of around $85,000 per year. Other relevant and potentially interesting characteristics include the share of population who have resided in the same home since last year as well as those that have moved from out state. Further, the data include information on residents working in a transportation (or related) or entertainment occupation, who may be more tolerant of aircraft noise[7], and those working from home or near their home, who may be more sensitive to aircraft noise pollution. Lastly, housing market attributes include the share of homes that are rented, the median number of bedrooms, and the share of homes and/or apartments that are vacant. Again, each of these socioeconomic statistics can arguably influence house prices and also affect a resident's propensity to complain; and therefore we must control for these potentially confounding factors in the first and second stage of our estimation.

The second, property-level dataset is build around Minneapolis home sales sourced from Open Minneapolis and generously shared by Pilgram and West (2018) [7], who study the

[7]These residents may be more tolerant because their employment may be directly related to aircraft operations and/or more noisy in nature. This increased exposure to noise may change the resident's propensity to complain. Reassuringly, our results do not depend on the inclusion of this regressor.

Table 2: Summary Statistics of Census data.

	(1) Mean	(2) Median	(3) SD	(4) Min	(5) Max
Demographic Variables					
Total Population ('000)	0.162	0.034	0.294	0.000	6.316
Total Median Age	39.716	39.200	5.161	21.011	58.900
Pop. Share Higher Ed.	0.633	0.638	0.099	0.151	0.940
Pop. Share White	0.896	0.936	0.108	0.115	0.998
Pop. Share Born Foreign	0.059	0.040	0.055	0.000	0.469
Pop. Share Family Households	0.745	0.776	0.107	0.134	0.942
Pop. Share Stayed in Same Home	0.898	0.910	0.056	0.318	1.000
Pop. Share Moved within State	0.035	0.030	0.025	0.000	0.245
Economic & Employment Variables					
Median Household Income ($'000)	84.851	83.839	20.526	11.188	235.556
Pop. Share in Transport./Entmt. Occup.	0.045	0.045	0.028	0.000	0.169
Pop. Share Worked out of State	0.001	0.000	0.001	0.000	0.010
Pop. Share Leaving for Work before 5AM	0.002	0.001	0.001	0.000	0.019
Pop. Share Work from Home	0.057	0.056	0.024	0.000	0.246
Pop. Share Walked to Work	0.015	0.012	0.020	0.000	0.406
Home Variables					
Share of Homes Rented	0.909	0.948	0.112	0.000	1.000
Median Number of Bedrooms	3.090	3.000	0.528	0.000	4.000
Share of Vacant Homes	0.048	0.045	0.030	0.000	0.271

Notes: The statistics are based on 52,224 observations from a sample of 6,528 distinct complaint grids generated by Metropolitan Airports Commission (MAC) and aggregated to an annual frequency from 2010 to 2017. Among all the grids, noise complaints were reported in 1,145 of them. Source: American Community Survey.

housing price premiums of the Minneapolis Blue Line light rail. The data provide information on the date a home sold, the sale price, the property's physical address and home characteristics, the Minneapolis community and neighborhood the property belongs to, and its coordinates. Based on these coordinates, we are able to map most properties into a specific grid and census tract. Based on this mapping, we merge property sales with the prevailing socioeconomic characteristics near the sold home and the level of predicted and actual residential noise complaints related to MSP aircraft operations.

Panel B of Table 1 summarizes the key property-level characteristics. On average, Minneapolis homes sold for around $270,000 between 2010 and 2017. The typical sold home had around 3 bedrooms and 2 bathrooms and every other home had a fireplace. The average home was build around 1941 and located around 9.3km away from the airport. Furthermore, the statistics suggest that sold Minneapolis property's tend to be located in neighborhoods with many noise complainers. Noise complaints in grids where sold properties are located average around 1,300 total complaints.

5 Results

Our discussion of the results is organized around the two stages of our empirical strategy. First, we investigate the likely nature of noise complaining residents around the MSP airport and evaluate the strength of our IV. Second, we explore the hedonic model and causal effect of aircraft noise pollution on Minneapolis house sale prices.

5.1 First Stage: The Nature of Noise Complainers

Table 3 builds the first-stage regression from a parsimonious model (column (1)) to the full model specification (columns (3) and (4)) that controls for demographic, economic, and housing market characteristics of the neighborhood surrounding the complaining residents. We focus our estimates on grids that record at least one complaint during a given year-hour pair. In each model, we include the IV of MSP aircraft operations for these year-hour pairs. The results are robust to the inclusion of grid-level characteristics and indicate that a 10% increase in hourly MSP operations is associated with around 100 additional hourly complaints per grid per year. The estimates are statistically significant at the 1% level and consistent across the full sample of grids (see columns (1)-(3) of Table 3)[8] and a restricted sample of grids for which we observe at least one Minneapolis home sale (see column (4) of Table 3).

Table 3: First Stage: Determinants of Noise Complaints

	(1)	(2)	(3)	(4)
Dependent Variable:		**All Counties**		**Minneapolis Only**
Noise Complaints	Demographics Controls Only	Demographics & Economic Only	Demographics & Economic & Housing	All Controls
ln(MSP Operations)	8.968***	9.179***	9.351***	10.611***
	(0.611)	(0.608)	(0.604)	(0.893)
ln(Total Population)	4.081***	4.194***	4.824***	6.505***
	(0.823)	(0.821)	(0.817)	(1.712)
ln(Median Age)	13.351*	15.995*	9.373	−16.874
	(6.558)	(6.664)	(6.770)	(18.902)
Pop. Share Higher Edu.	137.463***	25.851	37.405*	−24.143
	(10.243)	(14.966)	(15.005)	(26.904)
Pop. Share White	−66.293***	−112.208***	−102.095***	−43.284*
	(12.978)	(13.474)	(13.551)	(21.000)
Pop. Share Foreign Born	13.838	39.460*	60.596***	−55.725
	(18.006)	(18.063)	(18.190)	(31.694)
Pop. Share Family HH's	39.859***	−28.166**	−58.482***	43.181*
	(8.006)	(10.655)	(11.828)	(20.337)
Pop. Share Stayed in Same Home	10.706	80.183***	48.770*	−26.536
	(17.750)	(19.345)	(19.425)	(36.502)
Pop. Share Moved within State	115.630**	198.543***	170.632***	−275.715**
	(39.809)	(40.247)	(40.056)	(92.292)
ln(Median Income)		44.223***	37.208***	55.416***
		(5.944)	(6.048)	(10.839)
Pop. Share in Transportation of Entertainment Occup.		−235.414***	−242.641***	−191.484*
		(38.483)	(38.730)	(84.169)
Pop. Share Works out of State		−7571.015***	−7229.152***	−24065.374***
		(1376.404)	(1376.342)	(3185.884)

Continued on next page

[8]The full sample includes data from seven Minnesota counties surrounding the MSP airport including Anoka, Carver, Dakota, Ramsey, Washington, Scott, and Hennepin county.

Table 3 – *Continued from previous page*

	(1)	(2)	(3)	(4)
		All Counties		**Minneapolis Only**
	Demographics Controls Only	Demographics & Economic Only	Demographics & Economic & Housing	All Controls
Pop. Share Working before 5am		−1043.992	−1192.021	−386.867
		(764.319)	(759.867)	(1507.570)
Pop. Share Working from Home		299.306***	269.216***	169.195**
		(31.824)	(31.705)	(55.225)
Pop. Share Walking to Work		−71.275	−126.355***	183.103***
		(37.012)	(36.934)	(53.675)
Share of Homes Rented			−161.651***	−22.454
			(8.831)	(22.411)
Median # of Bedrooms			5.320**	−6.756
			(2.008)	(3.684)
Share of Homes Vacant			26.035	41.346
			(26.713)	(46.092)
Constant	−223.186***	−634.683***	−366.237***	−583.963***
	(28.858)	(64.646)	(66.302)	(143.910)
Country Fixed Effects	Y	Y	Y	Y
Year Fixed Effects	Y	Y	Y	Y
Adj. R^2	0.030	0.041	0.054	0.069
Observations	25601	25601	25601	8841
F statistic	37.575	39.999	48.012	25.159

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

With respect to the socioeconomic control variables we observe a number of expected and a few interesting patterns. As one might expect a rise in grid population raises the number of grid-level complaints. The age and birthplace of these residents, however, does not seem to be a good predictor of complaint behavior. There is some evidence to suggest that complaints rise in neighborhoods with more educated residents and in those localities with less turnover among residents living in these neighborhoods. Neighborhoods with a greater share of white residents register significantly fewer complaints. For the full sample (see column (3)) a percentage point increase in the share of white residents, for example, lowers the number of hourly complaints by about 1 per grid per year.

Median income appears to be a strong predictor of complaint behavior; as is the prevalence of residents working in transportation and entertainment occupations and those working from home. As one might expect, we find residents located in wealthier neighborhoods are more likely to complain. More specifically, a 1% increase in median household income is associated with a rise in local noise complaints of around 40 to 50 hourly complaints per grid per year. Furthermore, it appears that residents working in (or living near neighbors who work in) transportation and entertainment occupations - perhaps noisier industries - are more tolerant of aircraft noise pollution and less likely to complain. The same seems to be true for residents located in neighborhoods with a greater population share working out of the state of residence. In contrast, the estimates suggest that residents working from home are significantly more likely to complain. These latter two findings seem to suggest that the more time residents spend at home the more likely they are to complain about aircraft noise pollution. This is particularly relevant in the context of the COVID-19 pandemic, which has forced/enabled more people to work from home and perhaps increased the exposure to aircraft noise pollution.

Neighborhood housing market characteristics seem to be less relevant as it relates to noise complaint behavior. There is some evidence suggesting that renters are less likely to complain about aircraft noise than owners of noise affected properties.

Finally a comparison across columns (3) and (4) of Table 3 indicates that not all observed patterns are consistent across the seven sample counties. In column (4) we restrict the sample to grids for which we observe a property sale. These homes are located in Minneapolis, primarily Hennepin County. Among Minneapolis neighborhoods, education, race, and tenure seem to be less important determinants of complaint behavior in comparison to the other six counties. Moreover, among Minneapolis residents a greater prevalence of family households and folks walking to work seem to reverse the broader patterns for other counties and instead stimulate noise complaints from local residents.

Aside from these differences, MSP aircraft operations continue to have a positive correlation with noise complaints even among Minneapolis residents. We use the estimates from this final first-stage estimation with the restricted sample (column (4) of Table 3) to predict hourly noise complaints and aggregate this prediction to the annual-grid level. As in Friedt and Cohen (2021) [5] we account for (predicted) complaints in the four grids closest to each home sale.

5.2 Second Stage: Hedonic Analysis of House Sale Prices

This prediction of noise complaints is used in the second-stage regression. The results of this analysis are reported in Table 4. Among several interesting findings, the results clearly demonstrate (1) that aircraft noise pollution measured via noise complaints has a statistically and economically significant effect on home sale prices; and (2) that the issue of endogeneity is present when relying on noise complaints.

As to (1), the preferred specification shown in column (4) of Table 4 suggests that a 10% rise in noise complaints reduces house sale prices by nearly 0.1%. While this statistically significant estimates appears rather small, it is important to keep in mind that many grids experience large changes in complaints from year to year. Around 25% of our grid sample experience year-to-year reductions of 50%. Another 25% of our sample experiences increases in complaints of at least 167%. While the median grid experiences no change in annual complaints, the large right tail of this distributions skews the mean and leads to an average year-to-year complaint growth of around 750%. This suggests that some property's are subject to significant changes in aircraft noise pollution and that the owners of these homes experience considerable price discounts when selling their properties.

Figure 3 reiterates this point. The graph shows the effect of noise complaints on house sale prices located in grids with above median predicted noise complaints. Relative to a similar home located in a grid with zero noise complaints, a property located in grid with the median level of complaints will experience a sale price discount of around 2.9%. For those homes located in grids at the 90th percentile of noise complaints, the sale price discount increases to around 7%.

Table 4: Second Stage: Hedonic House Sale Price Analysis

	(1)	(2)	(3)	(4)	(5)
Dependent Variable:		**Predicted Complaints**			**Actual Complaints**
ln(Sale Price)	Home Attributes Only	Home & Demographic Controls	Home, Demographic, & Economic Controls	All Controls	All Controls
ln(Predicted Complaints)	0.003	−0.011***	−0.007**	−0.009***	
	(0.002)	(0.002)	(0.002)	(0.002)	
ln(Actual Complaints)					−0.015***
					(0.001)
ln(Distance (km))	0.165***	0.104***	0.087***	0.095***	0.077***
	(0.010)	(0.012)	(0.012)	(0.012)	(0.012)
# of Bathrooms	0.181***	0.176***	0.174***	0.173***	0.172***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
# of Bedrooms	0.067***	0.075***	0.076***	0.077***	0.073***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
# of Fireplaces	0.167***	0.151***	0.153***	0.153***	0.153***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Year Home Built	−0.001***	−0.001***	−0.001***	−0.001***	−0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ln(Total Population)		−0.037***	−0.069***	−0.059***	−0.043***
		(0.008)	(0.009)	(0.009)	(0.010)
ln(Median Age)		0.306***	0.205***	0.179***	0.127***
		(0.028)	(0.029)	(0.029)	(0.029)
Pop. Share Higher Edu.		0.441***	0.068	0.002	−0.015
		(0.039)	(0.047)	(0.048)	(0.048)
Pop. Share White		0.025	0.034	0.018	0.074*
		(0.034)	(0.036)	(0.036)	(0.036)
Pop. Share Foreign Born		0.358***	0.400***	0.273***	0.265***
		(0.058)	(0.059)	(0.060)	(0.058)
Pop. Share Family HH.'s		0.050	−0.226***	−0.111**	−0.116**
		(0.028)	(0.036)	(0.038)	(0.038)
Pop. Share in Same Home		0.137*	0.107*	0.103	0.313***
		(0.053)	(0.054)	(0.056)	(0.055)
Pop. Share moved in State		−0.281*	−0.373**	−0.178	−0.142
		(0.129)	(0.129)	(0.130)	(0.133)
ln(Median Income)			0.185***	0.216***	0.203***
			(0.014)	(0.014)	(0.014)
Pop. Share Transport. or Entertainment Occup.			0.193	0.387**	0.341**
			(0.128)	(0.129)	(0.132)
Pop. Share Working out of State			18.263***	15.345**	14.250**
			(5.012)	(5.036)	(5.062)
Pop. Share Working before 5am			1.075	1.165	−0.004
			(2.110)	(2.107)	(2.162)

Continued on next page

Table 4 – *Continued from previous page*

	(1)	(2)	(3)	(4)	(5)
		Predicted Complaints			**Actual**
	Home Attributes Only	Home & Demographic Controls	Home, Demographic, & Economic Controls	All Controls	**Complaints** All Controls
Pop. Share Working from Home			0.497***	0.316***	0.353***
			(0.094)	(0.095)	(0.101)
Pop. Share Walking to Work			0.469***	0.466***	0.435***
			(0.065)	(0.066)	(0.061)
Share of Homes Rented				0.308***	0.344***
				(0.037)	(0.044)
Median # of Bedrooms				−0.023***	−0.038***
				(0.006)	(0.006)
Share of Homes Vacant				−0.682***	−0.636***
				(0.071)	(0.073)
Constant	12.319***	11.733***	10.701***	10.093***	10.039***
	(0.166)	(0.192)	(0.223)	(0.228)	(0.235)
Year Fixed Effects	Y	Y	Y	Y	Y
Month Fixed Effects	Y	Y	Y	Y	Y
Community Fixed Effects	Y	Y	Y	Y	Y
Adj. R^2	0.629	0.644	0.648	0.650	0.643
Observations	27,849	23,546	23,531	23,526	21,751
F statistic	1,387.389	1,063.574	941.699	893.059	816.986

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

As to (2), Table 4 reveals that endogeneity is a concern when using noise complaints as a measure of aircraft noise pollution. Column (1) of Table 4 for example shows that the effect of noise complaints is estimated to be positive but insignificant when we fail to control for any of the likely characteristics of noise complainers. The expected omitted variable bias significantly attenuates our estimate. Control for the observable neighborhood attributes alleviates some of this bias and the noise complaint coefficient estimate returns to the expected sign and becomes statistically significant. However, a comparison between columns (4) and (5) of Table 4 demonstrates that not all confounding factors are observable. In column (5), we rely on actual noise complaints (rather than our predicted noise complaints shown in column (4)) we observe a notable increase in the estimate sale price discount. In other words, failure to instrument for noise complaints inflates the estimate of the causal impact of aircraft noise pollution on home sale prices by around 50%.

In addition to the negative effects of aircraft noise pollution, our findings point to many of the expected coefficient estimates. Property-specific characteristics, for example, matter. Homes with more bedrooms, bathrooms, fireplaces, and at greater distance from the airport command price premiums. Somewhat surprisingly, newer homes sell for lower prices than older ones, which speak to the fact that older homes are located in more desirable locations.

Demographic neighborhood characteristics also have significant effects on sale prices. Homes located in more densely populated neighborhoods sell for less, while properties located in neighborhoods with older populations and greater tenure among residents command a price premium. Relatedly, we find that neighborhoods with more family households are associated with lower home sale prices. A greater share of white neighbors tends to have a statically insignificant effect on home prices, whereas a greater share of foreign born residents stimulates sale prices.

As expected economic and employment-related neighborhood attributes are also important predictors of home values. The higher the median income in a given census tract the higher the property sale price. Similarly, homes located in neighborhoods where more residents working from home or walking to work command a price premium; as do homes located in neighborhoods where more residents commute to work out of state. In contrast, having more neighbors leaving for work early (before 5am) has no impact on house sale prices.

Finally, and unsurprisingly, neighborhood housing characteristics influence property sale prices. A greater share of rented homes drives sale prices up, whereas a greater share of vacant homes significantly lowers sale prices. The estimated effect on the median number of bedrooms of homes surrounding sold properties is negative.

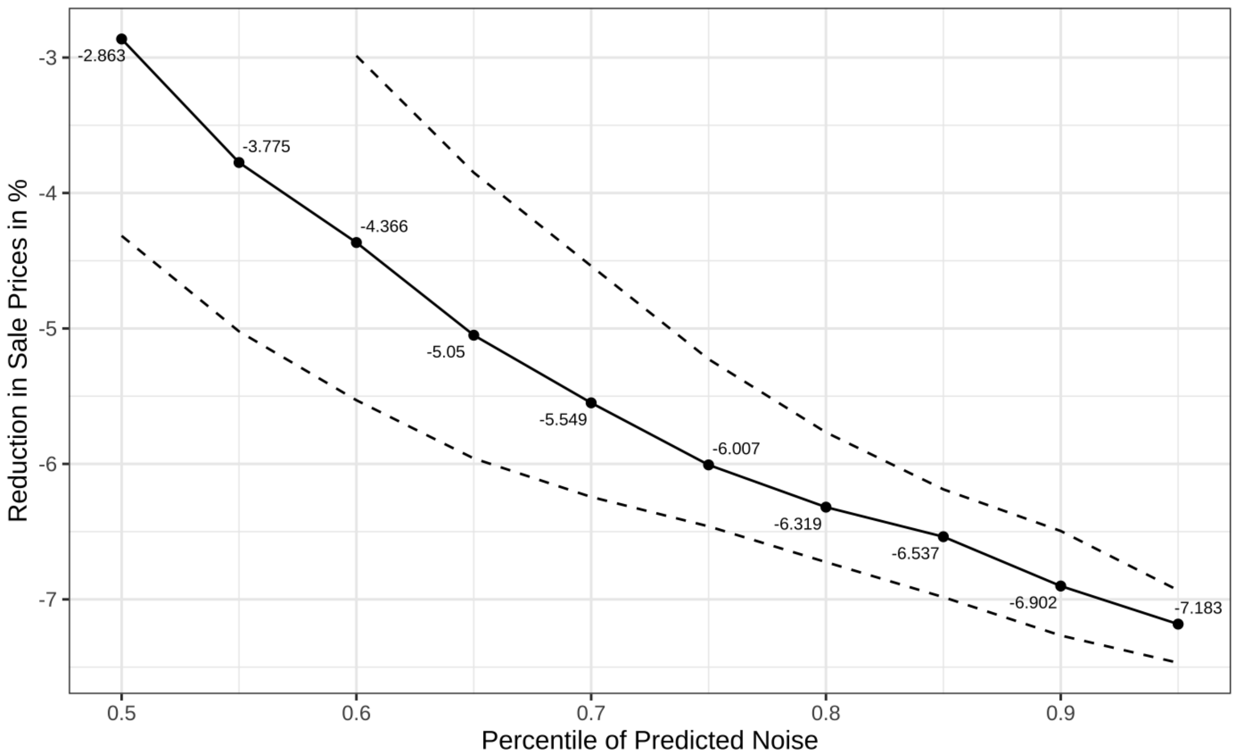


Figure 3: Sale Price Discounts of Predicted Noise Complaints by Percentile

Notes: The 95% confidence interval of each percentile (p) is derived using a Binomial method. The upper and lower bounds of percentile follow the function $p \pm 1.96 \times \sqrt{p(1-p)/100}$.

6 Conclusion

TBD

Our research shows that many residents are subject to aircraft noise pollution and voice their frustrations via noise complaints. We find that complaint behavior is non-random and that residents living in more affluent, educated, and non-white neighborhoods are more likely to complain. Importantly, we show that noise complaints are directly related to aircraft operations and therefore a relevant measure of aircraft noise pollution experienced by residents living near airports. Utilizing noise complaints in conjunctions with neighborhood characteristics and an instrumental variable, allows us to estimate the causal impact of aircraft noise pollution on house sale prices. We find statistically and economically significant sale price discounts that are concentrated in high complaint areas. Importantly, these vulnerable neighborhoods are extend beyond the published contour curves and are therefore often ignored when it comes to noise abatement policies.

Future Research TBD...

References

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[2] Mathias Basner et al. "Aviation noise impacts: state of the science". In: *Noise & health* 19.87 (2017), p. 41.

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[4] Jeffrey P Cohen and Cletus C Coughlin. "Spatial hedonic models of airport noise, proximity, and housing prices". In: *Journal of regional science* 48.5 (2008), pp. 859–878.

[5] Felix L Friedt and Jeffrey P Cohen. "Perception vs. reality: The aviation noise complaint effect on home prices". In: *Transportation Research Part D: Transport and Environment* 100 (2021), p. 103011.

[6] Felix L Friedt and Jeffrey P Cohen. "Valuation of noise pollution and abatement policy: Evidence from the minneapolis-st. paul international airport". In: *Land Economics* 97.1 (2021), pp. 107–136.

[7] Clemens A Pilgram and Sarah E West. "Fading premiums: The effect of light rail on residential property values in Minneapolis, Minnesota". In: *Regional Science and Urban Economics* 69 (2018), pp. 1–10.

Acknowledgement

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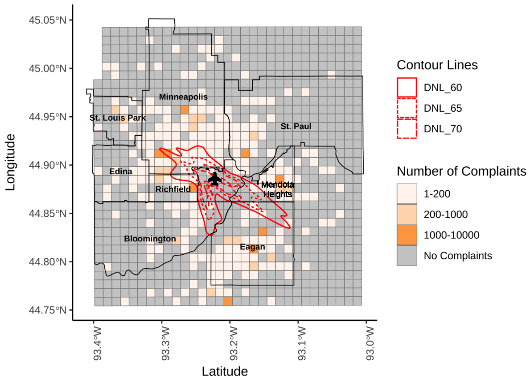
Appendix

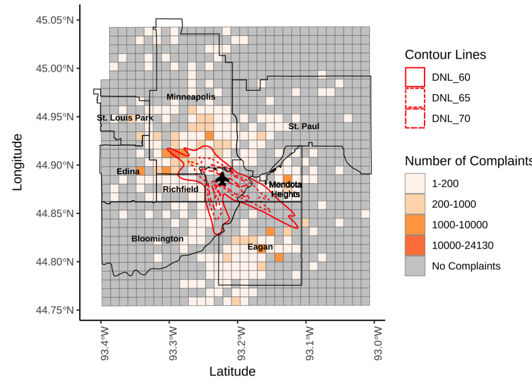
Table 5: Complaints outside of 60 dB contour

Year	Total Complaints Outside	Total Complaints	Share
2010	32631	38812	0.841
2011	42808	69772	0.614
2012	37299	44178	0.844
2013	69689	78861	0.884
2014	82947	97255	0.853
2015	93356	112701	0.828
2016	97904	116954	0.837
2017	123629	149051	0.829

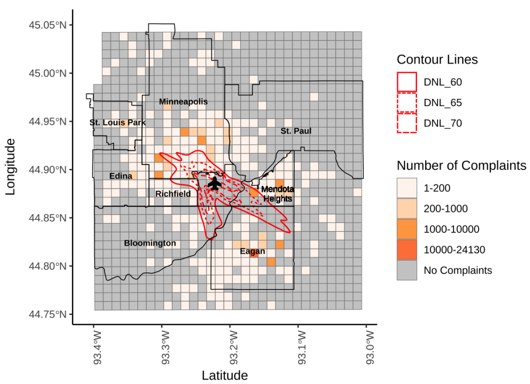
Notes:



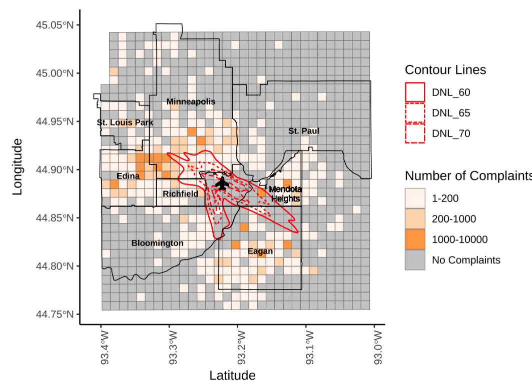
(a) 2010



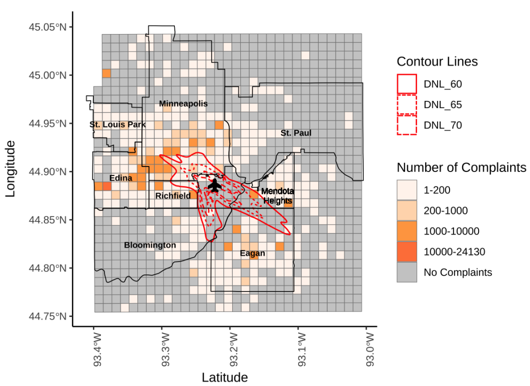
(b) 2011



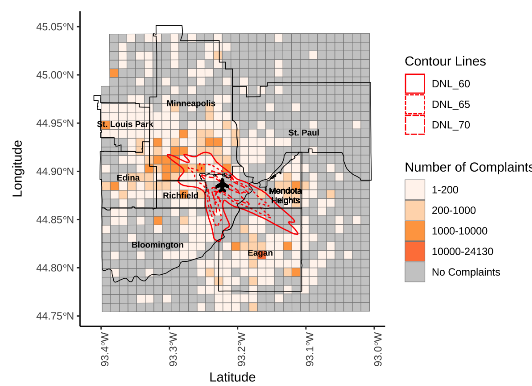
(c) 2012



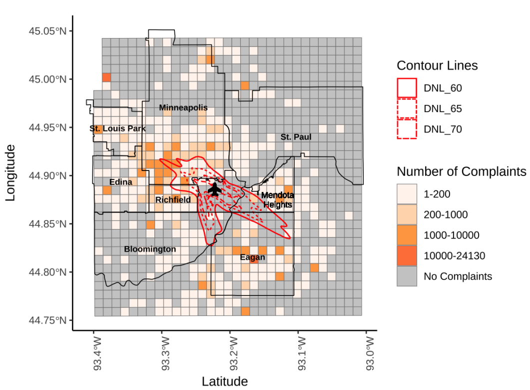
(d) 2013



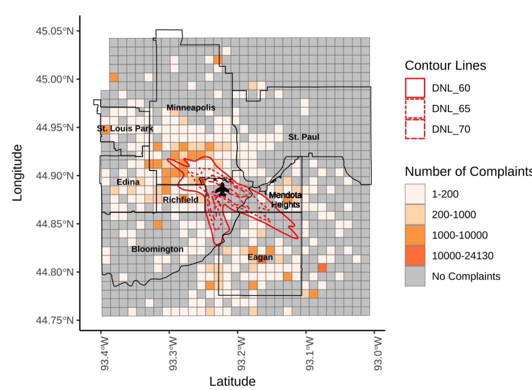
(e) 2014



(f) 2015

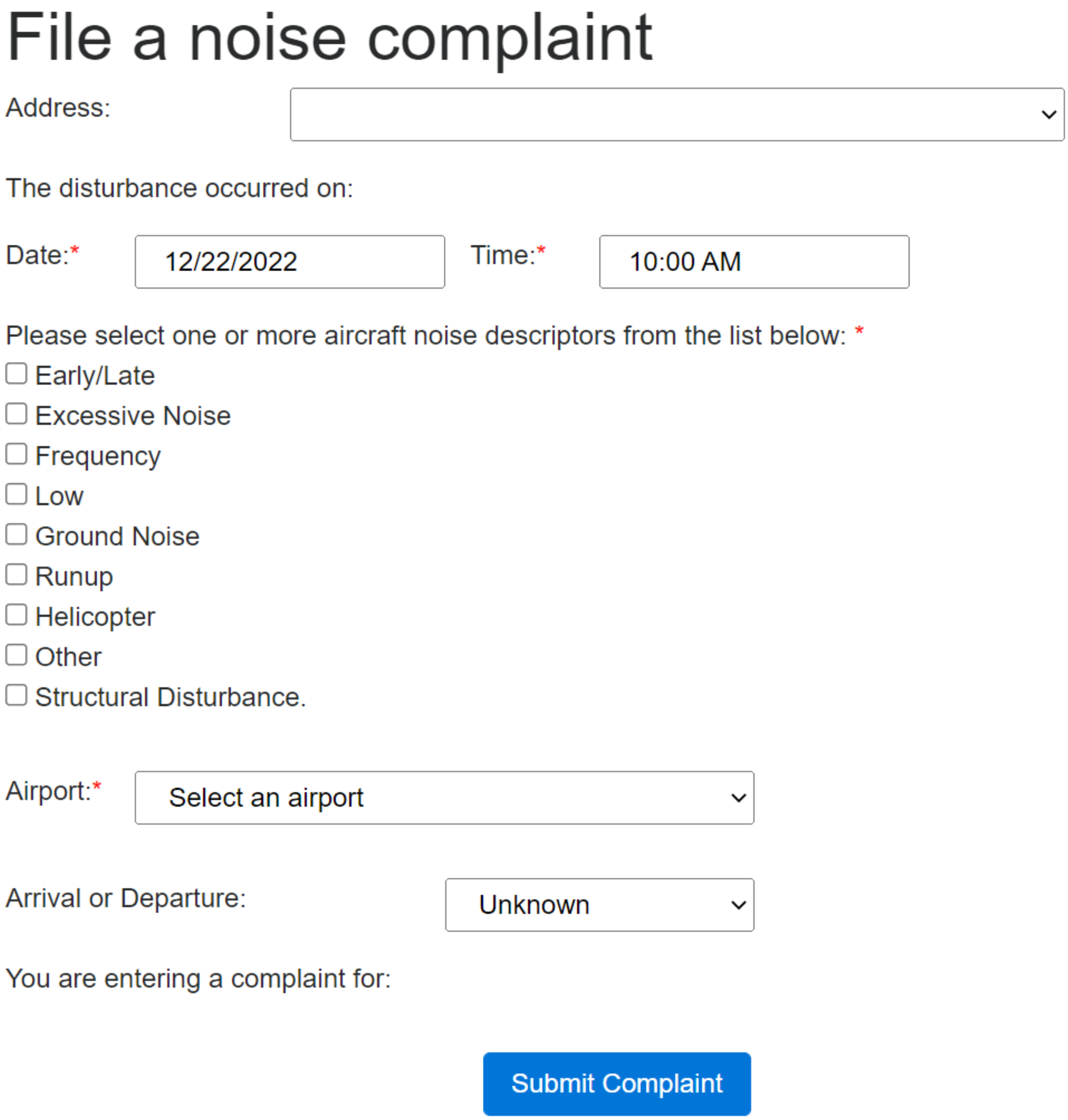


(g) 2016



(h) 2017

Figure 4: Annual noise complaints relative to noise contours surrounding MSP.



File a noise complaint

Address:

The disturbance occurred on:

Date:* 12/22/2022 Time:* 10:00 AM

Please select one or more aircraft noise descriptors from the list below: *

- [ ] Early/Late
- [ ] Excessive Noise
- [ ] Frequency
- [ ] Low
- [ ] Ground Noise
- [ ] Runup
- [ ] Helicopter
- [ ] Other
- [ ] Structural Disturbance.

Airport:* Select an airport

Arrival or Departure: Unknown

You are entering a complaint for:

Submit Complaint

Figure 5: MAC Noise Complaint Form