Aircraft Noise in Berlin Affects Quality of Life Even Outside the Airport Grounds

By Peter Eibich, Konstantin Kholodilin, Christian Krekel and Gert G. Wagner

Aircraft noise is a particularly problematic source of noise as many airports are located in or near major cities and, as a result, densely populated areas are affected. Data from the Berlin Aging Study II (Berliner Altersstudie II, BASE-II), whose socio-economic module is based on the longitudinal Socio-Economic Panel (SOEP) study which has been conducted since 1984, allows us to examine the effect of different levels of aircraft noise on the subjective well-being and health of the older residents of a major city, in this case Berlin. The findings show that the presence of aircraft noise, also measured using objective aircraft noise data, is associated with significantly reduced well-being, lower satisfaction with one's living environment, and poorer health. The association between well-being and a crossing altitude reduced by 100 meters is *given certain assumptions* – for crossing altitudes of between 1,000 and 2,500m – comparable to an income loss of between 30 and 117 euros per month.

Publicly and in the media, aircraft noise is often associated with restrictions on well-being and lasting damage to health. Fears of the impacts on individuals' health are reflected *inter alia* in discussions on future flight paths for the Berlin Brandenburg International Airport (BER).[1] Additionally, aircraft noise is associated with negative material consequences empirically evidenced through falling property and land prices.[2] The health effects of aircraft noise have already been analyzed in several medical research studies. The findings suggest that aircraft noise *inter alia* is also associated with an increased risk of cardiovascular diseases, sleep disorders in adults, and impaired cognitive development in children.[3] There are few studies in the economic literature that deal with the effects of aircraft noise.[4] For example, Van Praag and Baarsma (2005) studied whether the low cost of housing in the vicinity of Amsterdam airport offset the negative impact of the aircraft noise. They have found evidence leading them to conclude that loss of satisfaction through aircraft noise heavily outweighs the

1 See P. Neumann, "So macht der Fluglärm Anwohner krank," Berliner Zeitung, March 23, 2014, available online at http://www.berliner-zeitung.de/hauptstadtflughafen/klage-gegen-flughafen-tegel-so-macht-der-fluglaerm-an-wohner-krank,11546166,26635970.html, last accessed on December 16, 2014; and R. Kotsch, "Ungerecht, aber unausweichlich," Frankfurter Rundschau, January 26, 2012, available online at http://www.fr-online.de/politik/aerger-um-flugrouten-ueber-berlin-ungerecht-aber-unausweich-lich,1472596,11513756.html, last accessed on December 16, 2014.

2 Andreas Mense and Konstantin Kholodilin, "Noise expectations and house prices: the reaction of property prices to an airport expansion," The Annals of Regional Science, vol. 52(3) (2013): 763–797.

3 See A. Hansell et al., "Aircraft noise and cardiovascular disease near Heathrow airport in London: small area study," British Medical Journal, vol. 347 (2013): 5432; S. Perron et al., "Review of the effect of aircraft noise on sleep disturbance in adults," Noise & Health, vol. 14, no. 57 (2012): 58–67; S.A. Stansfeld et al., "Aircraft and road traffic noise and children's cognition and health: a cross-national study," The Lancet, vol. 365, no. 9475 (2005): 1942–1949.

4 See D.A. Black et al., "Aircraft noise exposure and resident's stress and hypertension: A public health perspective for airport environmental management," Journal of Air Transport Management, vol. 13, no. 5 (2007): 264–275; S. Boes et al., "Aircraft Noise, Health, And Residential Sorting: Evidence From Two Quasi-Experiments," Health Economics, vol. 22, no. 9 (2013): 1037–1051; and B.M.S. van Praag and B.E. Baarsma, "Using Happiness Surveys to Value Intangibles: The Case of Airport Noise," Economic Journal, vol. 115 (2005): 224–246.

positive effect of low housing costs. There are currently no reliable empirical analyses for Berlin. Data from the Berlin Aging Study II (*BASE-II*) has allowed us to examine the effects of aircraft noise in Berlin on a sample of primarily elderly residents.[5]

Methodological Challenges in Analyzing the Impact of Aircraft Noise

The key methodological problem inherent in the analysis of aircraft noise is that affected residential areas are not readily comparable with non-affected areas. For example, housing costs are often lower because affected neighborhoods are more likely to be located in the suburbs; accordingly, the socio-economic status of the residents in these districts is not generally representative of the entire population of the city. In addition, individuals perceive the same objective noise pollution very differently. Consequently, it is to be expected that individuals who are particularly sensitive to noise would not move to affected residential areas or would move away from a newly affected area. This selective mobility can lead to greater depreciation of housing prices and therefore the neighborhood as a whole.[6]

A simple comparison of well-being and health in affected and non-affected areas would, therefore, only give a distorted picture of the causal impact of aircraft noise because residents living in affected areas are frequently "resistant" individuals.[7]

Berlin Districts Affected by Aircraft Noise to Varying Degrees

The Berlin Aging Study II (*Berliner Altersstudie II, BASE-II*) is a multidisciplinary study on the determinants of successful aging. The sample (see Box 1) is comprised of a young subsample (aged between 20 and 35) and an old subsample (aged between 60 and 85). Of course, this means the sample cannot be considered representative of the Berlin population, neither in terms of geographical distribution nor in terms of the age structure of the residents. Nevertheless, the data provide a number of advantages that allow us to examine, using examples, the possible effects of aircraft noise to varying degrees on the subjective well-being and health of the Berlin population.

In particular, the data clearly indicate whether or not an individual lives in an area affected by noise[8] and whether or not that person is disturbed by the aircraft noise.[9] Accordingly, the empirical analysis can determine whether perceived aircraft noise has a negative effect on well-being and health in general) or whether the noise only affects sensitive residents. Nonetheless, despite it being possible to make this distinction, it is still difficult to draw conclusions about the residents of areas newly affected by aircraft noise since it is not known how many noise-sensitive people have moved away from the area near the airport, or have never moved there in the first place.

Figure 1 shows the extent of aircraft noise levels predicted in 60 areas of Berlin and the share of respondents who indicated they were disturbed by the presence of aircraft noise. The degree of aircraft noise was measured as the reciprocal value of the mean crossing altitude, i. e., the objective noise level is lower in areas with a high crossing altitude (shown as light gray shading) than in areas with a low crossing altitude (shown as dark gray shading). The figures indicate the percentage of respondents who stated they had been affected by aircraft noise and were disturbed by it.[10]

Of the 2,099 participants in the socio-economic module of the Berlin Aging Study II in the 2012 survey year, 728 people (about one-third) stated there was aircraft noise where they lived. Of these 728 survey participants, only 275 indicated they were disturbed by this aircraft noise. This represents about 35 percent of all individuals affected by aircraft noise and around 13 percent of the total sample. However, it should be noted that the geographical distribution of survey participants cannot be considered representative of the overall population of Berlin.

In areas exposed to higher levels of aircraft noise, this is more frequently perceived as disturbing (see Figure 1). Nevertheless, there are a number of areas set to be exposed to increased aircraft noise where only a few respondents are disturbed by it and vice versa. Equally,

5 For more information on the Berliner Altersstudie II (BASE–II) largely funded by the Federal Ministry for Education and Research (Bundesministerium für Bildung und Forschung, BMBF), see Lars Bertram et al., "Cohort Profile: The Berlin Aging Study II (BASE-II)," International Journal of Epidemiology, vol. 43, no. 3 (2014): 703–712 (the economic module based on the Socio-Economic Panel (SOEP) study is subsidized under the BMBF funding code 16SV5537).

6 See T. Winke, "Der Einfluss von erwartetem und tatsächlichem Fluglärm auf Wohnungspreise" (mimeo).

7 This effect was proven inter alia in the analyses by Boes et al., "Aircraft Noise."

8 The question was, "Is there aircraft noise where you live?"

9 The question was, "Does the aircraft noise in your area disturb you?"

10 For data protection reasons, areas with fewer than 20 observations were not included in this diagram. This affects the following areas, Gesundbrunnen, Kreuzberg Nord, Kreuzberg Süd, Kreuzberg Ost, Buch, Nördliches Weissensee, Südliches Weissensee, Südlicher Prenzlauer Berg, Charlottenburg-Wilmersdorf 1, Spandau 3, Schöneberg Nord, Lichtenrade, Gropiusstadt, Treptow-Köpenick 3, Hellersdorf, Biesdorf, Hohenschönhausen Nord, Hohenschönhausen Süd, Reinickendorf Ost, and Tegel. In the regression analyses, however, these areas were included, albeit with a smaller weight.

Box 1

BASE-II and SOEP

BASE-II is a joint multidisciplinary project involving the *Geriatrics* Research Group at the Charité, the Max Planck Institute for Human Development, the Max Planck Institute for Molecular Genetics, the Center for Medical Research at the University of Tübingen, and the research infrastructure Socio-Economic Panel (SOEP) at DIW Berlin. *BASE-II* is funded by the Ministry of Education and Research (VDI/VDE grant nos.: 16V5837, 16SV5537, 16SV5536K, and 16SV5538).

The aim of *BASE-II* is to research the determinants of successful aging. While in the previous study, *BASE-I*, the focus was on individuals aged 70 to 100, *BASE-II* focuses on the "young old," i.e., people aged 60 to 80. The sample comprised approximately 1,600 elderly people and a younger control group of approximately 600 individuals aged between 20 and 35.

Data collection included two medical studies at the Charité and two sessions of psychological and cognitive tests at the Max Planck Institute for Human Development. Participants also answered a questionnaire about their life circumstances and their biographies, similar to questionnaires used in the Germany-wide representative household survey SOEP.[1]

Table 1 describes the data used in the present study. The figures given are mean values for respondents affected and unaffected by aircraft noise. Respondents were asked to appraise their satisfaction with various aspects of life using an 11-point scale between 0 and 10, with 10 indicating the highest level of satisfaction. "Fatigue" indicates how often participants, by their own account, felt tired in the past four weeks. The response options ranged from "1-very rarely" to "5-very often." "Healthy eating" indicates to what degree respondents focused on eating a healthy diet; the value 1 stands for "very much" and the value of 4 for "not at all." For the "poor health" variable, participants assessed their current health on a scale from 1 ("very good") to 5 ("bad"); hence, the higher the value, the poorer the health. The migraine, hypertension, depression, and sleep disturbance variables are either "1" if respondents indicated they had been given the corresponding diagnosis in the past, or "0" if the respective condition had not been diagnosed. Similarly, the smoking variable is either "1" if a participant smokes or "0" if he/she does not. Risk appetite is measured on an 11-point scale from 0 ("not at all willing to take risks") to 10 ("very willing to take risks"). For the "political views" variable, respondents were asked to classify their political views on an 11-point scale from 0 ("far left") to 10 ("far right").

Table

Differences between affected and non-affected participants in the sample

Means

Variable	Mean	Number of individuals	Mean	Number of individuals
Are you affected by aircraft noise?	no		yes	
Life satisfaction	7.6	1 368	7.4	726
Health satisfaction	6.9	1 368	6.5	728
Sleep satisfaction	6.8	1 365	6.5	727
Satisfaction with friends	7.5	1 355	7.3	725
Satisfaction with dwelling	7.8	1 349	7.9	724
Satisfaction with residential area	8.3	1 362	7.9	722
Satisfaction with living environment	8.0	1 363	7.6	722
Poor health	2.5	1 368	2.7	727
Fatigue	3.0	1 371	3.0	724
Sleep duration on weekdays	7.2	1 369	7.1	725
Sleep duration on weekends	7.6	1 366	7.3	728
Sleep disturbance	0.08	1 371	0.13	728
Healthy eating	2.3	1 371	2.3	727
Smoking	0.13	1 368	0.11	726
Migraine	0.06	1 371	0.07	728
Hypertension	0.36	1 371	0.42	728
Depression	0.11	1 371	0.15	728
Risk appetite	5.1	1 348	5.1	717
Political views	4.0	1 328	4.0	716
Age	58.9	1 358	63.1	726
Share of men	0.54	1 371	0.52	728
Employed	0.23	1 371	0.17	728
Number of children	1.2	1 371	1.5	728
Married	0.50	1 371	0.62	728
Net household income	2 445.13	1 272	2 514.20	678
Years of education	13.5	1 371	13.8	728

Sources: BASE-II, Deutsche Flugsicherung, calculations by DIW Berlin.

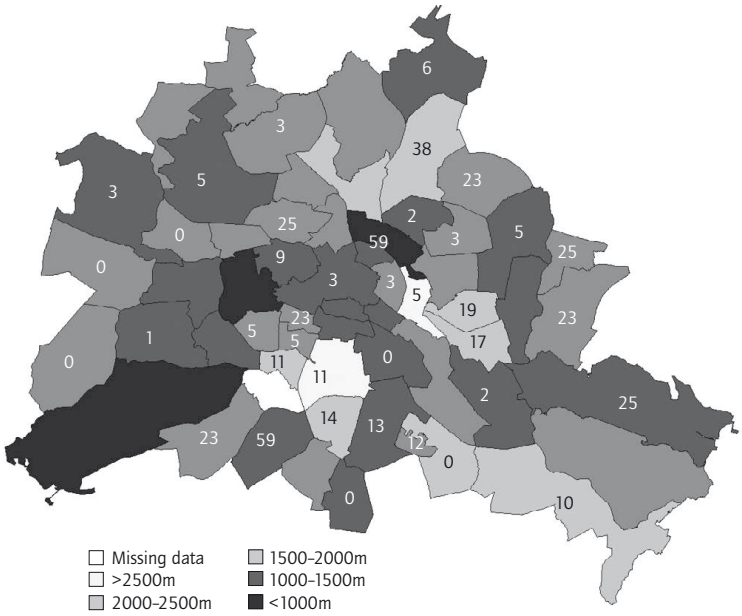
Participants affected by aircraft noise are on average less satisfied, are older and have a higher income than non-affected participants.

1 A. Boeckenhoff, "The Socio-Economic Module of the Berlin Aging Study II (SOEP-BASE): Description, Structure, and Questionnaire," SOEPpapers on Multidisciplinary Panel Data Research 568 (Berlin: 2013).

Figure 1

Average crossing altitude and self-reported disturbance by aircraft noise in Berlin

Units: altitude in meters and fractions of disturbance in percent



Sources: BASE-II, Deutsche Flugsicherung; calculations by DIW Berlin.

A low crossing altitude is associated with higher noise pollution in districts

it is clear that both the objective aircraft noise and the subjectively perceived noise pollution are not only restricted to areas in close proximity to Berlin's two current airports.

Aircraft Noise Affects Subjective Well-Being and Satisfaction with Housing

The present study examines the impact of aircraft noise on individuals' well-being and satisfaction with their housing. In addition, the effect on sleep and health is then measured according to various health indicators (see Table). To achieve this, a linear regression model is estimated to indicate the average impact of aircraft noise on the dependent variable. Aircraft noise is first measured with a binary variable, which is given the value "1" if a respondent claims to be affected by aircraft noise; otherwise it is given a value of "0." As mentioned above, since residents of areas affected by aircraft noise also differ from those in non-affected areas in terms of their noise sensitivity, and these differences even affect the dependent variable, additional control variables are used in the models to statistically control for systematic differences in age, marital status, income, employment status, education, and number of children of respondents in different regions.

The findings of the first model, in which the effect of the presence of aircraft noise is estimated, are shown in Figure 2. The various dependent variables are indicated on the vertical axis. The horizontal axis represents the extent of the influence of aircraft noise. The dots show the estimated impact on the relevant variable, after systematic differences in the control variables have been eliminated. The horizontal line represents the 95-percent confidence interval which indicates the degree of statistical accuracy of the estimate.

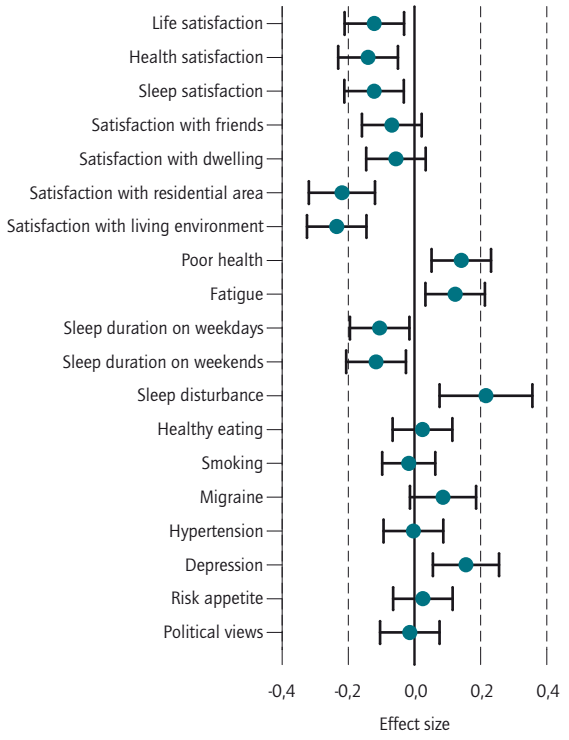
To allow a comparison of the different domains of well-being and health, the variables were scaled to a mean of zero and a standard deviation of one. This type of standardization ensures that the magnitude of the effects, which were measured on different scales, can be compared directly with one another (in standard deviations). If the confidence interval includes the value zero (vertical red line), there is a 95-percent probability that the estimated effect cannot be differentiated from zero, i. e., no effect. This means that the hypothesis "aircraft noise has no effect" cannot be dismissed.

It is clear from Figure 2 that individuals affected by aircraft noise have below-average satisfaction with their living conditions. Aircraft noise is negatively associated with general life satisfaction, satisfaction with own health, with the residential area, and the living environment (parks, noise levels, and cleanliness). Additionally, those affected consider their heath to be poor and frequently report sleep disorders or depression.

These findings cannot be interpreted as causal effects of aircraft noise on well-being and health without further assumptions. First, there is the issue mentioned above related to the selection of people in certain neighborhoods. Indeed, in such cases, the true impact of aircraft noise would be even greater than the effect estimated here because the potential negative impact on those who have moved away or never moved to the area in the first place cannot be taken into account. Second, other residential areas affected by aircraft noise are not readily comparable with neighborhoods unaffected by aircraft noise. For example, lower rents and housing prices might lead to individuals with a lower socio-economic status moving to those areas, meaning that unemployment or low income are the real causes of the reduced life satisfaction. Therefore, in the analyses, we statistically controlled for differences in age, marital status, income, employment status, education, and number of children of the respondents. Despite all this, unobserved selection bias cannot be completely ruled out.

Figure 2

Association between perceived aircraft noise and well-being and health
Unit: in standard deviations



Source: BASE-II, calculations by DIW Berlin.

Perceived aircraft noise is associated with reduced well-being and a lower satisfaction with the living environment

Box 2

Small-Scale Geo-Referencing

The survey data from the Berlin Aging Study II (*BASE-II*) and the Socio-Economic Panel (SOEP) study were anonymously linked to small-scale neighborhood information (e. g., regional unemployment rate, average income, and green space provision), allowing statistical analyses of the effect of neighborhood and contextual factors on a single individual. In order to establish the link, the survey data were given geo-references (e. g., zip codes or geo-coordinates). The geo-reference also allows other geo-referenced data (e. g., flight path data, as used in this study) to be linked to the survey data.

The respondents' addresses are converted into geographic coordinates at the fieldwork organization *TNS Sozialforschung*, directly. It stores the address but does not pass them on. The geographic coordinates of the addresses are randomly "blurred" within a certain radius so that, for example, only sections of road can be identified within densely populated areas but not precise addresses.[1] Further technical and organizational data protection measures assure the anonymity of participants at all times.[2]

1 For more information, see G. Knies and C. K. Spieß, "Regional Data in the German Socio-Economic Panel Study (SOEP)," DIW Data Documentation 17 (Berlin: 2007). Available online at http://www.diw.de/documents/publikationen/73/55738/diw_datadoc_2007-017.pdf, last accessed on August 14, 2014.

2 See J.Göbel and B. Pauer, "Datenschutzkonzept zur Nutzung von SOEPgeo im Forschungsdatenzentrum SOEP am DIW Berlin," Journal of Official Statistics Berlin-Brandenburg, issue 3 (2014): 42–47.

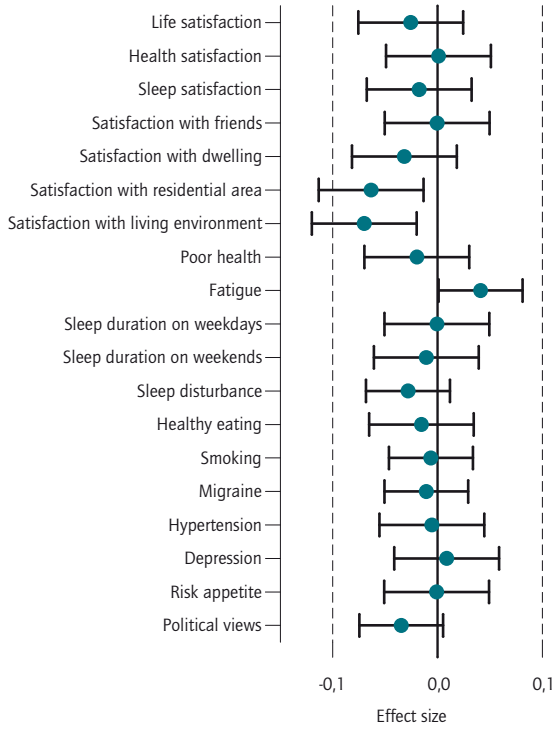
Another methodological limitation is that the residents themselves provided information about the noise pollution. This is particularly problematic if dissatisfied people more frequently state they are affected by aircraft noise than those who are satisfied. To exclude this possibility, objective data about crossing altitudes was used as a measure of aircraft noise (see Box 2). The findings confirm these conclusions based on the self-assessment of aircraft noise (see Figure 3). Thus, a lower crossing altitude is associated with reduced general life satisfaction and satisfaction with housing and the residential area. In addition, residents more frequently reported suffering from depression and fatigue.

The empirical models take into account differences in the monthly household income of survey respondents. This allows us to compare the correlation between crossing altitude and well-being with the correlation between household income and well-being. This method can be used to calculate the (hypothetical) amount of money that heavily affected households would have to receive monthly to achieve the same level of life satisfaction as less severely affected households.[11] The amount for a crossing altitude reduced by 100 meters is between 30 and 117 euros per month (depending on the affected domain). With regard to the differences in crossing alti-

11 This procedure was used, for example, by Stutzer and Frey (2008) to estimate the hypothetical compensation sum that commuters would have to receive. Van Praag and Baarsma (2005) use a similar method to quantify the cost of aircraft noise. See Stutzer, A. and Frey, B. S. "Stress that Doesn't Pay: The Commuting Paradox," Scandinavian Journal of Economics, vol. 110, no. 2 (2008): 339–366; Van Praag, B. M. S. and Baarsma, B. E., "Using Happiness Surveys" (2005).

Figure 3

Associations between inverse crossing altitude and well-being and health
Unit: in standard deviations



Sources: BASE-II, Deutsche Flugsicherung, calculations by DIW Berlin.

A lower crossing altitude is associated with reduced well-being, a lower satisfaction with the living environment and more frequent feelings of fatigue.

tude outlined in Figure 1, this means that households in strongly affected areas would have to earn 450 euros more each month to achieve a level of life satisfaction comparable with those households in areas hardly affected by aircraft noise. Of course, this sample calculation refers to an extreme case in which all assumptions of the underlying regression model hold, but nevertheless it illustrates the extent to which aircraft noise can affect quality of life.

In practice, a form of monetary compensation already occurs since rents and land prices are often lower in strongly affected areas.[12] The findings of a previous analysis show that even expectations of future noise pollution can cause substantial price falls in the local real estate market.[13] For every kilometer a flight corridor moves closer, a price decrease of 187 euros per square meter was observed. This means, for instance, a house located just 1.5 kilometers (linear distance) from the flight corridor will cost 561 euros per square meter less than an identical house over 4.5 kilometers away. A property with 80 square meters would therefore cost about 15,000 euros less if it were located one kilometer closer to a flight corridor. These examples suggest that the losses in life satisfaction caused by aircraft noise and described in this study have already been partly reflected in the housing market.

Box 3

Objective Aircraft Noise Data

The objective aircraft noise data are sourced from the German company responsible for air traffic control, *Deutsche Flugsicherung GmbH* (*DFS*). They cover the period May 1 through October 31, 2012. The dataset contains the coordinates and crossing altitudes of all aircraft taking off from or landing at Berlin's Schönefeld and Tegel airports. There are several observations for each flight, measured every four seconds, usually stopping after a flight time of four minutes. The dataset consists of over 16 million observations corresponding to 130,063 flights. In order to determine the average crossing altitude for various neighborhoods, the total area of Berlin was represented as a 50×50 grid. The average crossing altitude was then calculated for each grid cell using the individual observations associated with that cell. The inverse average crossing altitude is used as a measure of flight intensity and, therefore, of aircraft noise in the respective grid cell.

Conclusion

Cross-sectional analyzes alone do not allow any causal statements to be made. Based on the empirical findings presented in this report for a non-representative sample of primarily elderly residents of Berlin, it can be tentatively concluded that the presence of aircraft noise is associated with both reduced well-being and impaired health of those affected. The real extent of the negative impact of aircraft noise is underestimated as a result of particularly noise-sensitive people moving to quieter

12 Where noise pollution has been established, those moving to one of the affected areas are partly compensated for the noise pollution by lower rents and house prices. However, this argument does not hold true if there is a change to the noise pollution because then the residents affected do not benefit from falling real estate prices but will be additionally burdened.

13 See A. Mense and K. Kholodilin, "Erwartete Lärmbelastung durch Großflughafen mindert Immobilienpreise im Berliner Süden," DIW Wochenbericht, no. 37 (2012): 3–9; Winke, "Der Einfluss" for the Frankfurt am Main region.

neighborhoods. However, moving is not always possible or reasonable in all circumstances. Furthermore, (short-term) changes to flight paths might affect residents in previously unaffected neighborhoods. In both cases, there is a need for policy-makers to take steps to mitigate the negative effects of aircraft noise at local levels.

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