Continuation of Air Services at Berlin-Tegel and its Effects on Apartment Rental Prices

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Abstract

Berlin-Brandenburg airport (BER) became well-known far beyond German borders due to substantial planning problems and multiple opening delays. Originally planned to open in March 2012, BER finally opened in 2020, after seven delay announcements. Focusing on the two most surprising and meaningful announcements, these unexpected delays form an exogeneous shock for residents surrounding the largest existing airport, Berlin-Tegel, which was expected to close immediately upon opening of BER. We use these delay announcements as a quasi-experiment to analyze separately the effects on apartment rental prices of aircraft noise (due to arriving/departing flight paths) and airport proximity (accessibility). The results suggest there is a negative effect of aircraft noise on rental prices of 2% to 5%, while there are positive proximity effects from Berlin-Tegel of 1% to 3%. We consider heterogeneity using quantile regression and find the negative noise effects are larger for higher-priced apartments. We disentangle aircraft noise and other (environmental) noise effects, and herein find that aircraft noise lowers property values by 2% to 2.8% while properties facing additional environmental noise experience a separate 1.7% decrease. In a joint model of noise and proximity, we observe the proximity benefits and the noise externalities essentially cancel each other out.

Keywords: Real Estate Prices, Airports, Aviation Noise, Proximity, Germany

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Introduction

In this paper, we use a unique quasi-experiment in Berlin (Germany) to test the hypotheses that proximity to a major airport, and locations subjected to substantial aircraft noise, impact apartment rental prices. In separate models, we find that the noise discount is 2% to 5%, while the proximity benefits are in the range of 1% to 3%. Once we test prices of apartments affected jointly – by noise and proximity – against unaffected apartments, we do not find significant effects, suggesting that both effects cancel out each other.

The foundation of our analysis is based on the well-known hedonic housing price model of Rosen (1974). He postulates that the price of an apartment or a house equals the sum of the value of its individual characteristics. As later developed by Banzhaf et al. (2006) and others, these characteristics include not only the physical attributes of the respective housing object (such as number of rooms, bathrooms, living area etc.), but also local amenity and disamenity factors that influence the value of living within a specific neighborhood. Such factors may affect prices either positively (amenities) or negatively (disamenities). The investigation of such local factors has a long history in the field of housing economics (e.g. Davis, 2011 and Debrezion et al., 2007). While some of them are clearly attributed as amenities (such as city parks) or disamenities (such as pollution), others have unclear effects on housing prices.

Such an unclear overall effect also holds true for the case of airports. On the one hand, airports offer potential job opportunities and better connectivity, supporting the argument that airports are an amenity in the context of housing prices. On the other hand, the literature also demonstrates their role as a disamenity since aircraft cause noise pollution (e.g. Boes and Nüesch, 2011 and Winke, 2016). Noise is a major concern in developed countries since it seems to be negatively correlated with health outcomes and can reduce the quality of life. A constant increase of flights and passengers (in Germany the number of passengers increased from about 120 million in 1997 to 235 million in 2017[4]) also highlights the importance of external effects of airports on the property values in their local neighborhoods.

These hedonic modelling approaches are well-suited for our specific problem, but a solid identification strategy to pin down causal impacts is crucial in generating reliable results. Aiming to provide causal evidence of how airports impact real estate prices regarding amenities and disamenities, this paper benefits from the unexpected events regarding the construction (and delays in opening) of the new Berlin "Berlin-Brandenburg" airport (BER), and the associated delay in closing of the existing Tegel airport. Before German reunification, there were four airports in Berlin.[5] After reunification, the government intended to subsume all aviation-services of Berlin into one airport – BER. Finally in 2004, after a prolonged political process, the decision was made to erect BER close to the existing airport (Berlin-Schoenefeld)[6]. The construction work started on September 5th, 2006, also coinciding with termination plans for the existing airports. Specifically, Berlin-Tempelhof was planned to be closed in 2008, and the biggest remaining airport, Berlin-Tegel, was to be closed right after the opening of BER, with a planned closing date of November 2011. Over the course of the construction, the BER opening-date was adjusted to be June 2012, which did not result in too much public interest, and was not expected to have further housing price-effects.

[4] https://www.deutschlandinzahlen.de/tab/deutschland/infrastruktur/verkehr-und-transport/luftverkehr

[5] Because the Berlin hinterland was territory of the German Democratic Republic (GDR), West-Berlin government had to establish their airports (Tegel and Tempelhof) in very close proximity to densely populated parts of the city.

[6] Berlin-Schoenefeld is currently still operational as a part of BER. See: https://berlin-airport-brandenburg.com/ (accessed on 2/10/2022).

But, in May 2012 – still on track to open BER ahead of the announced schedule – substantial construction defects were detected. These defects made the planned opening impossible and at the same time meant air-services would be continued longer than expected at Tegel. Until then, the planned opening date (June 2012) was very convincing to residents, which can be illustrated by three facts. First, contracts with firms providing services at BER were fixed. Second, all passenger tickets were already assigned to the new airport. Third, invitations for the opening celebration had already been sent out to national and international government representatives. Regarding the old Tegel airport, up to this point, employees and employers, residents of the neighborhoods and others credibly expected airport activities at Tegel would cease within the next few weeks. In the further course of the development, the management of the airport then admitted in January 2013 that a completion date in 2013 (planned for October 2013 at that time) was not tenable and a new opening date was not foreseeable. Although this announcement did not lead to an abrupt change in the same manner as the May 2012 event, it did make clear to residents and apartment seekers that Tegel Airport would continue to exist in the medium term. After many years of further delays, BER finally opened (and Tegel finally closed) in November 2020. We analyze effects of delay announcements in this paper.

These delays form a set of exogenous events. The ongoing air-services announcements at Tegel (especially the announcement in May 2012) were not anticipated by any player in the housing markets – landlords, sellers, renters and buyers – and therefore, causal inferences of airport effects on housing prices in the neighborhood can be drawn from this event. As the delayed opening is more evident in a shorter perspective, we focus our estimations on the rental market as renters typically have shorter planning horizons than buyers. As 85% of households[7] in Berlin are renters, apartments are a much more representative housing class to consider than single-family residential properties.

Our approach based on geo-located housing data allows us to separately analyze an important airport-related amenity and a disamenity within our hedonic models. First, we address rental price discounts in the noise polluted areas (from approach and departure routes to/from Tegel) resulting from extended air service at Tegel; and second, we consider apartment price premia in those areas not polluted by noise but benefitting from proximity due to jobs and connectivity after the unexpected extension of flights at Tegel. A unique aspect of Tegel is that it is within the city of Berlin, and many residents live close but are not connected to any railway, metro or tram line. However, there were express buses from Berlin city center to the airport which were also accessible to the residents near the airport. After the closure of Tegel, the connectivity to the city center significantly worsened. Besides the city center and airport connectivity, Tegel provided jobs for almost 7,000 employees. For these reasons, we test the hypothesis that there are also substantial positive effects for residents in the areas surrounding the airport. A difference-in-differences approach (diff-in-diff) reveals a 2% to 5% aircraft noise pollution price-discount for rental apartments (for a daytime threshold of 55dB). A separate diff-in-diff estimation reveals a 1% to 3% price premium for proximity (defined for 3 separate models as less than 10 minutes, less than 15 minutes, or less than 20 minutes driving time to the airport), while restricting attention to those apartments unaffected by noise pollution.

Although there exists a range of studies that analyze different aspects of airport amenities and disamenities, our approach broadly contributes to that literature. In our framework with an airport that is expected to close, the effects of both proximity and noise come into play, and inhabitants have concrete information about both factors (i.e., specific jobs available, and detailed information about aircraft noise levels). This is not the case when an airport is newly opened. Jobs are only job opportunities and noise-pollution is only a theoretical projection for a new airport, which is not felt as strongly by residents before flights occur. Moreover, the effects may become relevant at different

[7] Statistisches Jahrbuch 2018 – Berlin, table 19.05 values for 2013; source: https://www.statistik-berlin-brandenburg.de/produkte/Jahrbuch/BE_Kap_2018.asp (downloaded 8/27/2019)

points in time. With an airport closure, noise remains until the shutdown, and forward-looking employees may value the proximity less over time as the closure date approaches.

The Tegel closing date delays, together with the certainty that all operations will permanently cease in the medium-term, allow us to estimate the overall effect of noise and proximity. This estimate of the overall effect enables us to address the question of whether positive or negative factors dominate. This question is difficult to analyze credibly with other frameworks because prior to an ordinary opening, most job opportunities do not exist, and noise pollution is only a theoretical value. When we run the combined analyses in our setup, the results suggest that the prolonged noise pollution effect offsets the continuation of the proximity effect in the noisiest areas, especially when the expected Tegel operations are long-lasting. Furthermore, we can observe adaptation processes before delays come into play, meaning that noise-polluted apartments catch-up in their prices compared to similar apartments which are not affected by aircraft noise. We also consider other types of noise, and find the properties exposed to noise from other sources experience a 1.7% additional rental price discount.

Finally, various apartments might be impacted differently by aircraft noise. To unmask this potential heterogeneity, we estimate a quantile regression model. These quantile regression estimates indicate that higher priced apartments tend to experience a larger noise discount than lower priced apartments. This implies that perhaps individuals seeking "nicer" apartments (proxied for by price) have a higher willingness to pay for avoiding airport-related noise than individuals seeking lower-quality (i.e., lower-priced) apartments.

The remainder of this paper is structured as follows. First, we briefly summarize the literature before we present details of our data. In the fourth section the estimation strategy is displayed. Estimation results are reported in section 5 while section 6 concludes.

Literature Review

Before the Covid-19 pandemic, air traffic was increasing in most countries. Airports offered local residents job opportunities and access to air travel, but also aircraft noise. Therefore, the overall willingness to pay for living in the surrounding neighborhoods of an airport is ambiguous. The existing literature on the effects of aviation noise on housing prices includes a meta-study of Nelson (2004), which finds a consensus of negative effects on housing prices. Jud and Winkler (2006) study an expansion of the Greensboro/High Point/Winston Salem airport in North Carolina. They find that the expansion announcement had a short-term house price impact of -9% within 2.5 miles of the airport.

Besides the disamenities from noise, the positive effects of the proximity to airports have also been investigated. Brueckner (2003) observes positive employment effects related to airline traffic. Tomkins et al. (1998) and McMilllen (2004) show that there are positive effects on house prices from proximity to airports. Therefore, analysis focusing on only one of these potential effects (noise or accessibility) are prone to neglect important findings. This was addressed by Espey and Lopez (2000), Lipscomb (2003), Cohen and Coughlin (2008, 2009), and Ahlfeldt and Maennig (2010). Cohen and Coughlin (2008, 2009) and Lipscomb (2003) consider the Atlanta, Georgia airport, which is one of the largest airports in the world. They all find evidence that the negative noise effects tend to outweigh positive proximity effects.

Despite this existing literature, the implementation of causal identification strategies remains a challenging task in the context of airport effects because changes are plagued by endogeneity (Breidenbach, 2015). In general, the existence of an airport does not change over time. Even if an airport is newly constructed, its location is not randomly chosen. There are usually longstanding announcements (so people anticipate the airport effects, resulting in a slowly fading-in process instead of a clear cut-off). The issue of simultaneity between airport noise and housing prices is another concern for identification of causal effects. We therefore analyze the effects of a set of unexpected delays in closing of an airport. This strategy has the advantage that residents can already observe the aviation noise and the ongoing operation had not been expected.

Another issue to consider is the difference in noise exposure impacts on owner-occupied residential real estate, opposed to rental residential real estate. If a resident purchases a house that is exposed to a given level of noise, and expects to live in that house for decades, the present discounted value of the noise damage is expected to be greater than it would be if the homeowner was planning to stay for only 1 to 3 years. But the fixed costs involved with buying a house typically imply a homeowner would be planning to live in a house for at least several years. Therefore, those residents with a relatively short time horizon for living in a particular location tend to rent rather than purchase. This implies the present value of the expected damages from a given level of airport noise should be relatively low for renters. Some other papers analyze the effects of the BER opening on housing prices, such as Mense and Kholodilin (2014), who analyze the effects of the publication of future routing of the air traffic on housing prices. Though their approach is a sensible framework, we believe that our approach of relying on the exogeneity of the delay announcements and the immediate impact of ongoing noise offers a unique framework for important insights.

More generally, Ahlfeldt and Maennig (2015) have shown that homeowners react differently than renters when voting on the new "aviation concept" that was to create the Berlin-Brandenburg" (BER) airport and to close Tegel. Renters expected the benefits of proximity to BER would outweigh the noise costs, and therefore would drive up the price of apartments relative to owner-occupied homes. On average, more renters were found to oppose the "airport concept" referendum and homeowners were found to be supportive. This leads one to ponder the question of how renters near Tegel might react to a delay in the opening of BER, compared with homeowners. Such a delay might prolong the exposure to noise for renters, and it also might prolong the amount of time that they can access Tegel for employment opportunities and/or travel convenience. The authors' objective was to examine whether homeowners - who were likely to benefit from the capitalization from proximity to BER and reduced noise after closure of Berlin-Tempelhof – more strongly supported the 2008 referendum than renters. They find highly significant (and positive) treatment effects from the announcement of this concept. Homeowners might be expected to benefit more. Renters tend to have a shorter time horizon to live in a property. Therefore, we expect prolonged noise exposure for a renter might bring down their willingness to pay more than for a homeowner who might expect to be in the home for decades after the closure (and therefore benefit for a long period of time from the closure of Tegel).

There is an emerging literature on the impacts of the new BER airport on residential real estate prices. For instance, Mense and Kholodilin (2014) consider the announcement of the flight paths for BER as an exogenous event to identify the impacts of expected noise on real estate prices. The expected drop in house prices was in the range of 8%-13%, depending on the altitude of the flight paths near a given property.

Also in the European context, Boes and Nüesch (2011) examine apartment rents near Zurich, Switzerland's airport. They find that for every additional decibel of noise, apartment rents fall by approximately 0.5%. In contrast to many of the airport noise studies that have been done for owners of houses, this estimate is relatively small. But that may be attributable to the fact that renters tend to have a shorter expected time horizon for living in the property. In a study of the Geneva, Switzerland airport, Baranzini and Ramirez (2005) find somewhat larger impacts, in the range of 1% per decibel, for impacts of aircraft noise on apartment rents. However, their results likely imply correlation rather than causality.

In our analysis, we consider both noise and proximity, using a solid identification strategy to pin down the causal relationships. Our exogenous shocks are the series of delay announcements for the construction of the new BER airport that coincide with the closing of Tegel. This approach provides us with a unique way to identify the causal impacts of noise on residential property rental prices, and of proximity on residential rental property prices.

Data

For the analysis of the unexpected continuation of flight operations at Berlin-Tegel (referring to the delayed opening of BER) on rental property prices surrounding Tegel, we merge data from several different sources, including geo-referenced Berlin housing data, small-scale drivetimes to the airport, data on aviation-noise pollution as well as some background characteristics of the neighborhoods. The data on housing prices stem from the **RWI GEO-RED** data, obtained from the FDZ Ruhr at RWI (Boelmann et al 2019a, 2019b). The data we use covers all advertisements of residential properties for rent throughout Germany between 2007 and March 2019, which the FDZ Ruhr at RWI obtained from the real estate online platform called ImmobilienScout24. ImmobilienScout24 is the biggest real estate online platform in Germany[8]. The data for all advertisements include characteristics such as size (plot size and number of rooms), year of construction, number of floors, and indicators for whether there is a balcony, a guest bathroom, and others. Besides characteristics of the apartments, the asking price is included in the dataset.[9] Further, this dataset includes geo-coded address information for about 95% of the objects. Characteristics of rental properties are summarized in Table A.1 in the appendix. A detailed description of the data can be found in Boelmann and Schaffner (2019). We use the data from 2010 to March 2019 for the analysis.

We estimate the driving time from each property to Berlin-Tegel, which we include in our regressions as a control for proximity of the airport. This driving time is calculated from each listed apartment to the airport. The driving time is calculated by the FDZ Ruhr at RWI (**RWI GEO-GRID DRIVETIME**) and is based on OpenStreetMap data. Further, we estimate the travel time by public transport. For this purpose, the transportation time for apartments is taken from the Berlin public transport provider www.bvg.de. It is the shortest travelling time for departures between 9:00 am and 9:30 am.

The noise data for aviation noise are taken from Senatsverwaltung für Umwelt, Verkehr und Klimaschutz in Berlin. Their webpage provides noise maps for every type of noise separately. Therefore, aviation noise can be separately collected, as well as separated from other types of noise (which we consider in our heterogeneity analysis). The noise pollution of 55dB and more are displayed in Figure 2 for all aviation noise resulting from Berlin-Tegel airport. This noise information can be linked to the housing objects obtained from RWI GEO-RED by the exact geo-code.[10]

Finally, the dataset is enhanced by neighborhood characteristics taken from the **RWI-GEO-GRID** data. The RWI-GEO-GRID data cover socio-economic information of the residents for all populated 1x1 km grid cells in Germany (based on the EU-regulation “INSPIRE”). As the geo-coded housing data (RWI-GEO-RED) also refers to these grid cells, the datasets can easily be merged to each other (specifically, each apartment can be assigned a grid-level value for the demographic characteristics). The RWI-GEO-GRID dataset comprises data on population by gender as well as by age group, purchasing power, credit default risk classes, unemployment, cars, and migration background of the residents. The data are described in Breidenbach and Eilers (2018). We apply v8 of the data covering the years 2005 and 2009-

[8] ImmobilienScout24 claims to represent 86% of all published advertisements.

[9] Apartment rental price negotiations are not very common in Germany at all. Further, rents in Berlin have been increasing faster than the number of apartments, so the market power of renters in Berlin is low.

[10] The noise contours show the exact noise values by any airplane-related noise based on flight paths, which also includes ground noise from airplanes at the airport.

2016 (RWI/microm 2019). Table 1 summarizes characteristics of the advertised rental properties and the local neighborhood by the different treatment groups.

Estimation Strategy

Our estimation strategy relies on the idea that (potential) renters of apartments expect Tegel will close immediately after the opening of BER – following the previously decided-upon plans. Consequently, for apartments affected by aviation noise from Tegel airport, renters assume that the aircraft noise from takeoffs/landings at Tegel will vanish soon. Prices are assumed to adapt towards a new equilibrium without aircraft noise pollution. Similar mechanisms are expected for the positive features of the airport (jobs accessibility and connectivity); prices are assumed to adapt towards a new equilibrium without the amenities after Tegel is closed.

Table 1 Descriptive Statistics for Treated and Non-Treated Apartment Rental Properties

		≤ 15 min drivetime		> 15 min drivetime
Variable	Total	< 55dB	≥ 55dB	
Observations	186 170	154 166	32 004	536 660
Ln(rent per sqm)	2.062	2.102	1.867	2.028
Age	48.448	48.909	46.225	40.192
Floor size	75.279	77.088	66.571	73.414
Floor of the apartment	1.721	1.787	1.401	1.922
Number of floors of the building	3.036	3.295	1.792	3.324
Number of rooms of the apartment	2.368	2.374	2.342	2.436
Balcony	0.66	0.644	0.74	0.675
Quality of apartment				
Unknown	0.549	0.51	0.715	0.556
Simple	0.010	0.010	0.011	0.009
Normal	0.212	0.218	0.185	0.202
Sophisticated	0.205	0.231	0.083	0.205
Deluxe	0.027	0.031	0.006	0.028
Quality of house				
First occupancy	0.051	0.061	0.006	0.049
First occupancy after reconstruction	0.094	0.100	0.065	0.079
Like new	0.034	0.038	0.017	0.053
Reconstructed	0.0652	0.07	0.043	0.102
Modernized	0.06	0.064	0.041	0.062
Completely renovated	0.134	0.141	0.103	0.097
Well kempt	0.23	0.216	0.299	0.204
Needs renovation	0.014	0.013	0.018	0.010
By arrangement	0.009	0.009	0.008	0.007
Dilapidated	$1.1*10^{-5}$	$1.3*10^{-5}$	0	$1.7*10^{-5}$
Unknown	0.308	0.289	0.408	0.33
Houses in neighborhood	618.982	622.25	603.22	636.37
Persons in neighborhood	35,991	37,012	31,072	34,548
Households in neighborhood	6,392	6,773	4,561	5,651

SOURCE: Authors' calculations based on RWI-GEO-RED

Consequently, the adaptation processes are stopped or impeded when delays of the opening are announced. Therefore, the announcements constitute an important aspect of our identification strategy. Yet, there were at least seven official announcements of delayed openings, which allow us to identify effects in the housing market. Table 2 gives an overview of all dates of delay-announcements that occurred during the construction work at BER (column 1). Moreover, Table 2 includes the planned opening (before the delay) in column 2 and the declared new opening (column 3).

As the announced delays are much more relevant in a short planning horizon rather than in a long run perspective, we focus our analyses on rents. Renters (and rent seekers) typically have a shorter planning horizon than buyers. Additionally, the majority of German households are renters (58%). This share is substantially larger in Berlin (where our analysis focuses) with a tenant share of 85%.[11] Moreover, we focus on apartments instead of houses since houses for rent are a rather rare exception within metropolitan areas such as Berlin.

We aim at building our estimation strategy on a diff-in-diff approach. For this purpose, we need a temporal differentiation of the pre- and post-treatment phase and a spatial differentiation into a treatment and a control group. Meaningful announcement dates (in the sense of our estimation strategy) need to fulfill two criteria. First, the announcements should have higher relevance for our empirical analysis if they are made close to the original planned (or rescheduled) opening date. This ensures that market participants react directly after the delay was declared. Potential residents searching for apartments in the neighborhoods near Tegel expect that the airport will close within the subsequent weeks after the opening of the new airport. Second, the announced time span until the new declared opening must be sufficiently long. Otherwise, market participants may not react to the delay.

Table 2 Opening Date Delay Announcements for Berlin-Brandenburg Airport (BER)

Announcement Date	Planned Opening	Declared New Opening
Sep 2006		Oct 30th 2011
Jun 2010	Oct 30th 2011	Jun 3rd 2012
May 2012	Jun 03rd 2012	Mar 17th 2013
Sep 2012	Mar 17th 2013	Oct 27th 2013
Jan 2013	Oct 27th 2013	not declared
Dec 2014	not declared	2nd half of 2017
Jan 2017	2nd half of 2017	2018
Dec 2017	2018	Oct 2020
Sep 2017	Referendum: Citizen Movements achieved a referendum on the future status of Berlin-Tegel. A majority of Berlin's inhabitants voted for "remaining Tegel open" after the opening of BER.	

SOURCE: Authors' research based on media articles.

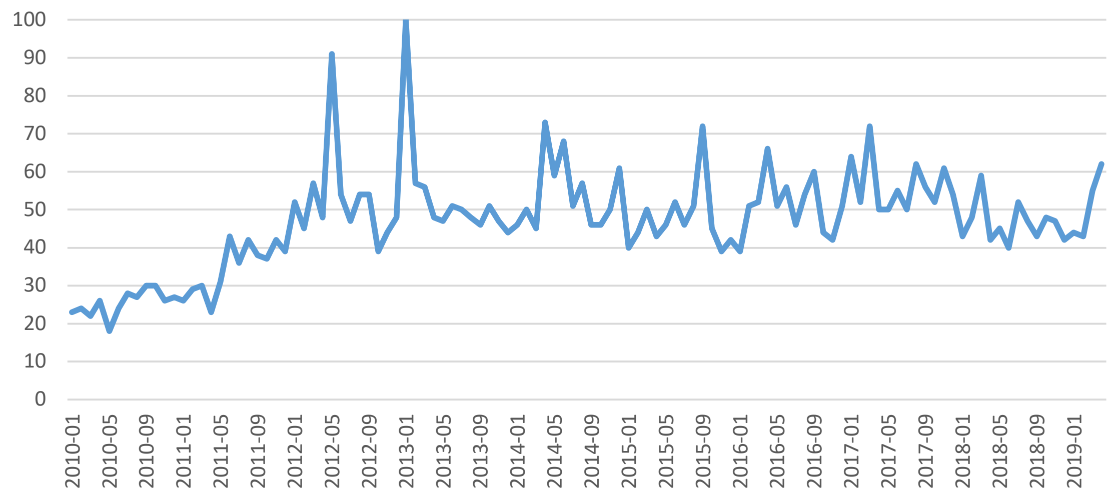
Following these two criteria, the first delay announcement (in June 2010) should be of low importance. The announcement was made quite long before the planned opening (seventeen months ahead of October 2011), making it hard to interpret when market participants reacted. Furthermore, the announced delay was rather short (eight months), therefore it is unclear if market participants reacted at all. This kind of delay is quite common for big building projects.

[11]Statistisches Jahrbuch 2018 – Berlin, table 19.05 values for 2013; source: https://www.statistik-berlin-brandenburg.de/produkte/Jahrbuch/BE_Kap_2018.asp (downloaded 8/27/2019).

From this perspective, the announcements in May 2012 and in January 2013 form good candidates for stronger reactions in the rental housing market because they were made closely before the planned opening (especially in the case of May 2012)[12] and the declared opening was far ahead (especially in the case of January 2013 when no new opening was declared).[13] Additionally, we run setups controlling for each announced delay shown in Table 2.

The prominence in the media also underpins the importance of the announcements in May 2012 and in January 2013. We quantify this relevance by Google Trends analyses (Figure 1) showing that the search for the term "BER" had two outstanding peaks over time, the first around May 2012 and the second around January 2013. Before the beginning of May 2012, newspaper articles focused on the opening and the corresponding ceremonies. This changed when the delay was declared four weeks before the planned opening, forming nationwide and international media attention. This attention was accelerated further when more skepticism regarding the construction was spread in German media during the following months (especially with the announcement in January 2013, giving no new planned opening date).

Figure 1 Google trends searches for "BER"



SOURCE: Google Trends; searching for "BER" in the period January 2010 to March 2019 (covering our observed period). Executed on August, 29th 2019.

Following the idea to implement a diff-in-diff strategy, we need to define a spatial control group, which credibly reflects developments in a counterfactual situation without a treatment. As we follow two different identifications – the case of analyzing effects of the noise-pollution on housing prices, and for the case of analyzing effects of the connectivity to an airport on housing prices – a control group needs to be defined separately for each approach. Figure 2 illustrates the different groups exploited in our settings on the aggregated level of 1x1 km grids. Grids filled with the yellow to red layer are affected by a mean noise pollution of at least 55dB. Herein, the orange/red colors indicate those grids which

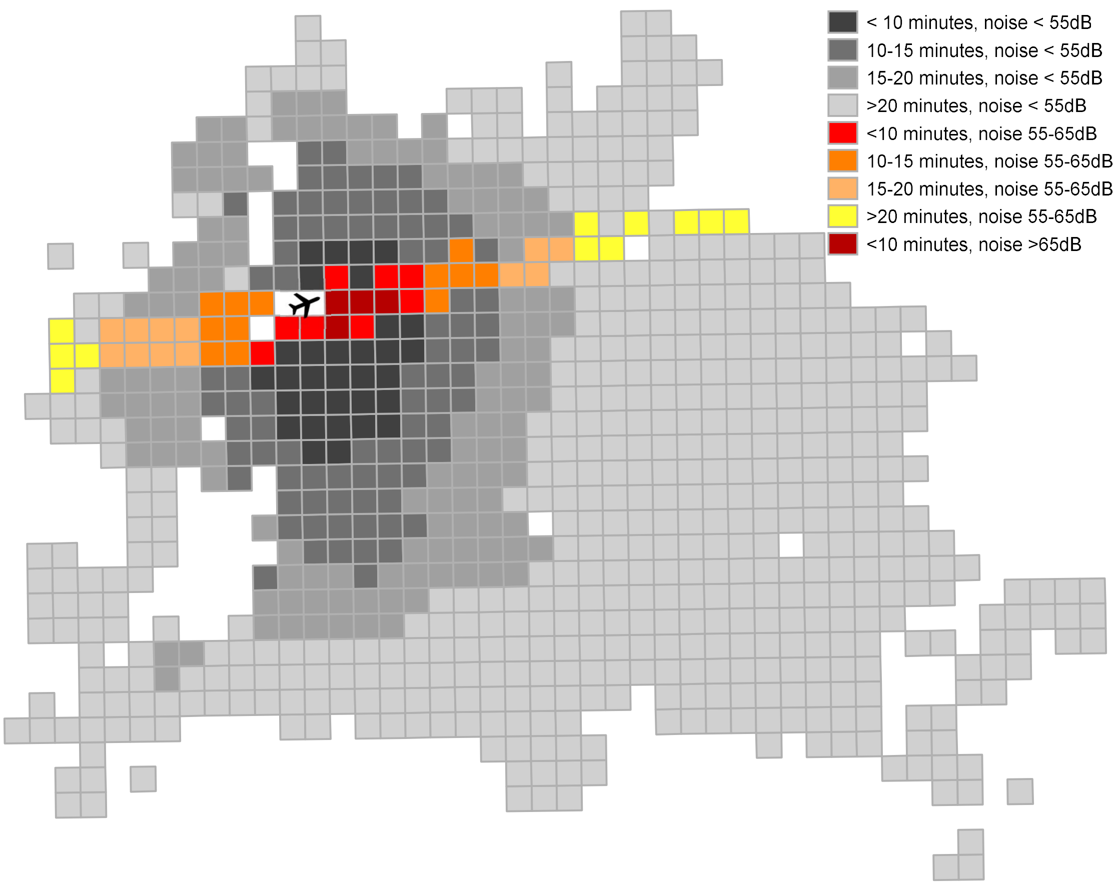
[12] Tickets for a flight after the opening were all assigned to the new airport (BER). There were no signs that the opening would be shifted and that Berlin-Tegel would continue operating.

[13] In this context, the December 2014 announcement forms another interesting date. Going back to the delay that occurred two prior years beforehand (January 2013), no rescheduled opening date was announced. Thus, the announcement in December 2014 is expected to have a reverse effect, since the opening becomes more concrete. Noise polluted objects are expected to be positively affected after the December 2014 announcement, and vice-versa for objects which benefit from jobs and connectivity.

also have a short driving time to Tegel. Those grids colored light orange or yellow are exposed to noise but without a short driving time (above 15 minutes and 20 minutes, respectively).

For the case of noise-analysis, most objects suffering from noise (typically located in the approach and take-off routes) also benefit from the airport proximity at the same time as they are located close to the airport (orange/red). Thus, a control group which is not affected by the airport at all is not suitable as it implicitly refers to the situation without both – noise and connectivity. The connectivity (utilized by the drivetime) is illustrated by the grey layer. Regarding the estimations, we shrink the treatment group on objects located in the orange/red grids and the control group on objects located in the two dark-grey grids. In this sense, both the control and treatment group gain from proximity to the airport but only the treatment group is also affected by the noise pollution. The noise-pollution is defined by thresholds of 55dB and 60dB. Our dataset does not allow us to observe noise pollution below the threshold of 55 dB.

Figure 2 Noise and drive time in the areas surrounding of Tegel airport



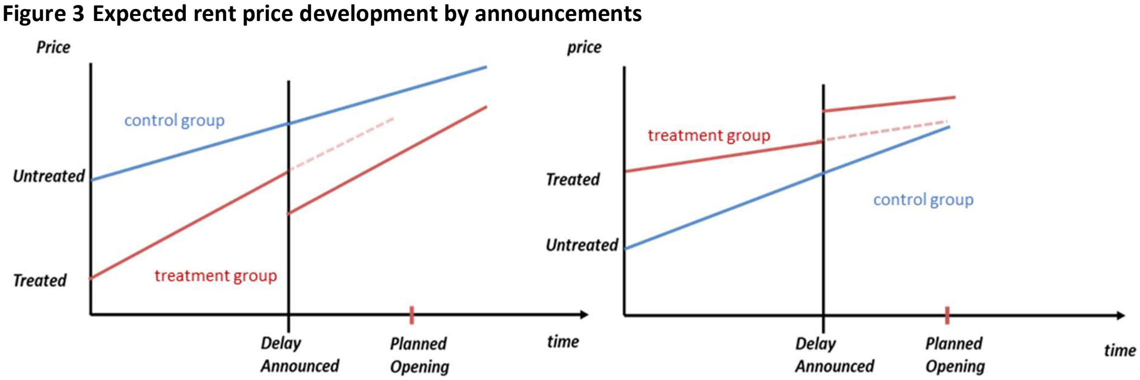
SOURCE: RWI-GEO-RED, drivetime to Berlin-Tegel calculated by algorithm obtained from RWI-GEO-DRIVETIME. Noise-pollution obtained from Senatsverwaltung Berlin. Despite having individual apartment level values for drivetime and noise classes, which we use in our analysis, the map illustrates the numbers aggregated to 1x1km grid cells, to provide a better overview. The airplane indicates the location of Tegel airport.

For the case of the drivetime analysis, we define our control group by all objects in Berlin which are not located in the proximity of Tegel - defined by a threshold of a maximum drivetime to Tegel of 20 minutes respectively. These locations are indicated by the lightest grey category. The three dark grey categories define the treatment group of objects within a drivetime below 20 minutes. In our empirical results below, we also consider a robustness check with drivetime of at most 15 minutes. The twofold effects of connectivity and noise are also present in this setting. Thus, we exclude all properties affected by noise (above 55dB, all yellow, orange and red grids) in the treatment and control group to avoid biases by the noise pollution (yellow to red grids).

Figure 3 illustrates our hypothesis graphically for noise effects (Panel A) and proximity effects (Panel B) and thus provides a helpful overview for effects we model in the estimations. In general, we assume an increasing price trend all over Berlin. Regarding the apartments treated by noise from the Berlin-Tegel airport, we assume that rents are on a lower level since noise-pollution forms a disamenity (Panel A). The issue of pre-trends deserves some discussion here, as they are somewhat more complicated than the typical difference-in-differences approach. In our analysis we are focusing on treatment effects arising due to announcements of the ***delays*** in Tegel's closure. These delays occur after the initial announcement that the airport will be closing. Our dataset does not extend back to the date of the original announcement of the airport closing, but we expect that leading up to that point of the initial closing announcement there were parallel trends, and there would have been a structural break at that closure announcement date. In fact, these assumptions are verified by Ahlfeldt and Maennig (2015), who as a part of their paper study the closing announcement of Tegel. From that closing announcement date forward, rental prices of noise-exposed properties would be expected to start to catch-up to non-noise exposed properties, and therefore the trends after that time would not be parallel (however those trends would not be expected to have significant kinks). Our dataset (and analysis) begins in this time-period when the trends are not parallel.[14]

Following the idea that the projected closing of Tegel (and opening of BER) influences rents, we expect rent prices of treated apartments to catch up with the prices of untreated apartments over time. The treatment (announcements of a delay) is mapped by the vertical line in Panel A of Figure 3. Once the delay is announced, noise is expected to remain longer and the catching-up of rents in treated areas is assumed to be shifted back for the treatment group. This is the key hypothesis that we test with our noise analysis.

Figure 3 Expected rent price development by announcements



Panel A: Noise Treatment **Panel B: Proximity Treatment**

Figure 3, Panel B illustrates our hypotheses for rent effects of proximity to the airport before and after the announced delays. Again, both groups are characterized by an increasing price trend, but the rent level for the treated group (close to the airport without high noise pollution) is higher since the proximity (without noise pollution) is an amenity. However, it is assumed that prices will converge

[14] An analogous version of the classic test for parallel trends in our context would consider whether there were additional structural breaks (i.e., kinks in the trends) shortly before the first delay announcement. We test whether there are additional, spurious structural breaks occurring in these trends before the first delay announcement. With some placebo tests using a set of "fake" delay announcements (one in each month leading up to the actual first delay announcement), we find no significant evidence of additional structural breaks before the first actual delay announcement.

between the treated and untreated groups because Tegel will close, and the amenity will disappear. At the time of the delay announcement, prospective residents' expectations change, leading to an upward shift in prices for the treated group, followed by the converging process starting again after this shift. Our proximity hypothesis tests for this structural break in the treatment group at the time of the delay announcements.

Our diff-in-diff approach for the noise effect is defined by

$$y_{ignt} = \alpha_1 N_n + \alpha_2 T_t + X_i\beta_1 + Z_{gt}\beta_2 + \gamma_1 t + \gamma_2 N_n t + \boldsymbol{\delta Treat_{nt}} + \theta_g + u_{ignt}, \qquad (1)$$

with y_{ignt} being the log of price per square meter of rental apartment i in grid cell g, noise value n at month t. N_n is a dummy for noise-polluted locations, T_t takes the value 1 if the property was advertised for rent after the respective announcement and 0 otherwise. Characteristics of the property are included in X_i and time-variant characteristics of the 1x1 km cell (number of households, number of inhabitants, purchasing power, drivetime to Tegel) are included in Z_{gt} (grid-characteristics). θ_g are grid cell fixed effects. The time trends are defined as a monthly overall linear time trend (γ_1) and an additional monthly time-trend for all noise-polluted objects (γ_2). This group specific time trend reflects the expected catch-up process of treated apartments.[15] Finally, $\boldsymbol{Treat_{nt}}$ (defined as the product of N_n and T_t) is the treatment effect that takes the value 1 for noise-polluted properties after the respective announcement, and zero otherwise. In order to extract the pure noise effect, we only exploit those apartments in the noise equation that are located in the proximity (maximum of 15 minutes driving time) to the airport. Apartments within this proximity that are exposed to noise form the treatment group, while those not affected by noise (within the same distance) form the control group.[16]

In the equations above, we assume the airport has a negative impact on housing prices due to noise pollution. However, it is also possible that there are positive effects on the apartments close by. We define a diff-in diff estimation that is similar to equation (1), again including group specific time trends, covering potential price adaptions prior to the announcement (see Figure 3). In order to extract the pure drivetime effect, we only exploit those apartments not exposed to noise. $\widetilde{N_d}$ takes the value 1 if the apartment is within the drive time of d minutes and if it is not treated by aviation noise (of 55dB or higher). The model is estimated for different drivetime cut-offs ($\boldsymbol{d}$). The treatment group specific variables here are defined by the group specific fixed effect for drive time, $\widetilde{N_d}$, the group specific time trend $\widetilde{N_d}\, t$, and the interaction of $\widetilde{N_d}$ and T_t, which is the treatment effect $\boldsymbol{Treat_{dt}}$. The control group comprises all apartments neither located within the drivetime nor exposed to noise.

$$y_{igdt} = \alpha_1 \widetilde{N_d} + \alpha_2 T_t + X_i\beta_1 + Z_{gt}\beta_2 + \gamma_1 t + \gamma_2 \widetilde{N_d} t + \boldsymbol{\delta Treat_{dt}} + \theta_g + u_{idt} \qquad (2)$$

We estimate the models (1) and (2) separately, using the two announcements (May 2012 and January 2013). For a fixed observation period, results from the separate estimation for each event may be biased since the treatment for the first event (May 2012) is depicted in the pre-treatment period for the case of the January 2013 event. We therefore include the timeframe of both announcements in one regression to identify a dynamic treatment effect and additionally build up a model in the same way as when including all announcements shown in Table 2. The model is:

[15] Due to these expected group specific trends, which we model in our specification, we do not base our identification strategy on a standard diff- in-diff parallel trend assumption before the announcements of the delays. See footnote 14, as well as the related discussion above.

[16] Technically, N_n comprises those apartments with noise and close proximity to Tegel. Noise polluted apartments, not in proximity are excluded from this equation. We flag those apartments with the indicator $\widetilde{N_n}$ in the course of the paper.

$$y_{ignt} = \alpha_1 N_n + X_i\beta_1 + Z_{gt}\beta_2 + \gamma_1 t + \gamma_2 N_n t + \sum_a(\boldsymbol{\delta_a Treat_{ant}} + \alpha_{2a}T_{at}) + \theta_g + u_{int}, \quad (3a)$$

$$y_{igdt} = \alpha_1 N_d + X_i\beta_1 + Z_{gt}\beta_2 + \gamma_1 t + \gamma_2 N_d t + \sum_a(\boldsymbol{\delta_a Treat_{adt}} + \alpha_{2a}T_{at}) + \theta_g + u_{idt}, \quad (3b)$$

where a is the respective announcement. T_{at} takes the value 1 if the property was advertised after announcement a and zero otherwise. $\boldsymbol{Treat_{ant}}$ $(N_n * T_{at})$ is the treatment effect dummy that takes the value 1 for noise-polluted properties after the announcement a, and zero otherwise. $\boldsymbol{Treat_{adt}}$ $(N_d * T_{at})$ is the diff-in-diff dummy (i.e., the treatment effect) that takes the value 1 for properties close to the airport after the announcement a and zero otherwise.

Up until this point, our samples (for noise and drivetime estimations) have been restricted geographically to provide the best possible identification strategy. In that sense, our noise estimations are restricted to those dwellings in proximity to the airport and either exposed to noise pollution (treatment group) or not exposed (control group) – ensuring that the estimation is not plagued by differing proximity to the airport. By definition, the restriction of the sample (which increases comparability) prevents us from estimating an overall effect of the airport operation, which simultaneously addresses the positive (proximity) and negative (noise) effects. In a similar sense, we exclude noise polluted apartments from the drivetime estimation.

Ultimately, we focus on the question of whether positive or negative effects of an airport dominate the rental prices of apartments nearby an airport. In general, such a question is difficult to answer regarding other airport settings. For example, in the case of newly opened airports, positive effects due to job opportunities at the airport cannot materialize until the operations of an airport have started. In contrast, the designated flight paths for approaches and take-offs allow for a proxy of the future noise pollution far before the airport ultimately starts its services. Nevertheless, until the airport opens, noise pollution is only a theoretical value which is not experienced yet by potential inhabitants. Both (positive and negative) effects do not affect inhabitants simultaneously in a standard setting of newly opened airports. Therefore, studying airport openings does not allow for conclusions of whether the amenities or disamenities dominate. The unique setting with Tegel (with several delays in the closure) forms an exception since inhabitants know about the noise as well as the jobs/accessibility, and both factors are expected to vanish immediately once the airport closes. The delay announcements encompass both effects at the same time, and consequently, allow us to compare both effects since they come into play simultaneously. Because of the unique setting with Tegel (bringing both effects into play at the same time), now we adapt our identification strategy to account for both effects at the same time, in an attempt to gain insights of whether one of the effects outweighs the other.

Here, we need to define three different zones by noise and proximity: i) dwellings only affected by noise but not by proximity ($\widetilde{N_n}$)[17], ii) dwellings only affected by proximity but not by noise ($\widetilde{N_d}$) and iii) dwellings affected by both – noise and proximity ($N_n N_d$)[18]. By these definitions there is no geographical overlap of these three groups. An apartment can be in only one of these three groups. Once again, T_t is an indicator equal to 1 for an apartment being listed after a particular delay announcement, and 0 otherwise. The treatment effect $\boldsymbol{Treat_{ndt}}$ comprises the apartments located in proximity to the airport and exposed to noise after the respective announcement of a delay. Equation (4) illustrates the corresponding model, which takes all available observations into account (instead of

[17] The variable $\widetilde{N_n}$ differs from the definition of N_n, applied in the previous analysis of noise effects. While $\widetilde{N_n}$ focuses on apartments exposed to noise but NOT within proximity of the airport, the previously applied N_n comprises all apartments exposed to noise and located within the defined proximity to the airport.
[18] Technically, ($N_n N_d$) is identical to the dummy (N_n). We refer to notation with the interaction as it better illustrates the composition of this group.

truncating the model), with those apartments neither affected by noise nor by proximity as the control group:

$$y_{igdt} = \alpha_d \widetilde{N}_d + \alpha_n \widetilde{N}_n + \alpha_{nd} N_n N_d + \alpha_2 T_t + X_i \beta_1 + Z_{gt} \beta_2 + \gamma_1 t + \gamma_2 \widetilde{N}_n t + \gamma_3 \widetilde{N}_d t + \boldsymbol{\delta_d} \widetilde{N_d} \boldsymbol{T_t} + \boldsymbol{\delta_n} \widetilde{N_n} \boldsymbol{T_t} + \boldsymbol{\delta_{dn} Treat_{ndt}} + u_{idnt}, \quad (4)$$

Results

We start with the effects of (unexpected) ongoing noise pollution, focusing on the two major announcements of delays (May 2012 and January 2013). After testing potential effects for each announcement (including the shorter delays and the less ad-hoc announcements), we test for heterogeneity in our results. Making use of the detailed small-scale information at hand, we test whether other forms of noise pollution, object characteristics, or socio-economic characteristics of the neighborhood affect our main findings. Subsequently, we consider the drivetime effects following an analogous approach. Finally, we combine the models with both drivetime and noise pollution effects.

Starting with the noise pollution model of eq. (1), we restrict the analysis to all observations that are within a driving time of 15 minutes to Tegel airport. We also consider public transport travel times, but this has negligible effects on the results. We conduct an analysis of numbers of cars and trucks on the roads near the airport and find little variation in road traffic near the airport, which implies that changes in road traffic over time is not contaminating our analysis. Within the 15 minutes drive time area, the treatment group consists of all apartments that suffer from aviation noise of at least 55dB or 60dB. Focusing on the main announcements of delays in May 2012 and January 2013, we estimate six models shown in Table 3. Columns 1 and 2 focus on the 55dB threshold for May 2012 and January 2013. Columns 3 and 4 focus on the 60dB for both announcements. Finally, columns 5 and 6 reflect the model from eq. (3a) including both announcements (May 2012 and January 2013), defining treated apartments by either 55dB (column 5) or 60dB (column 6). The control group is defined by all apartments that experience less than 55dB of aviation noise (and similarly in the setting with 60dB as treatment) but have a similar driving time to the airport (maximum 15 minutes). The results in Table 3 indicate a positive time trend of slightly less than 0.5% for all apartments (nominal prices in Berlin), as expected for this particular market. In general, those apartments treated with noise have lower prices, indicated by the negative sign of the noise dummy in the range of approximately -2% to -4%, but show a positive catching-up process, indicated by the trend for noise polluted apartments. These three general findings indicate negative price premia of noise pollution and the converging process approaching the closing of Tegel as expected in Figure 3.

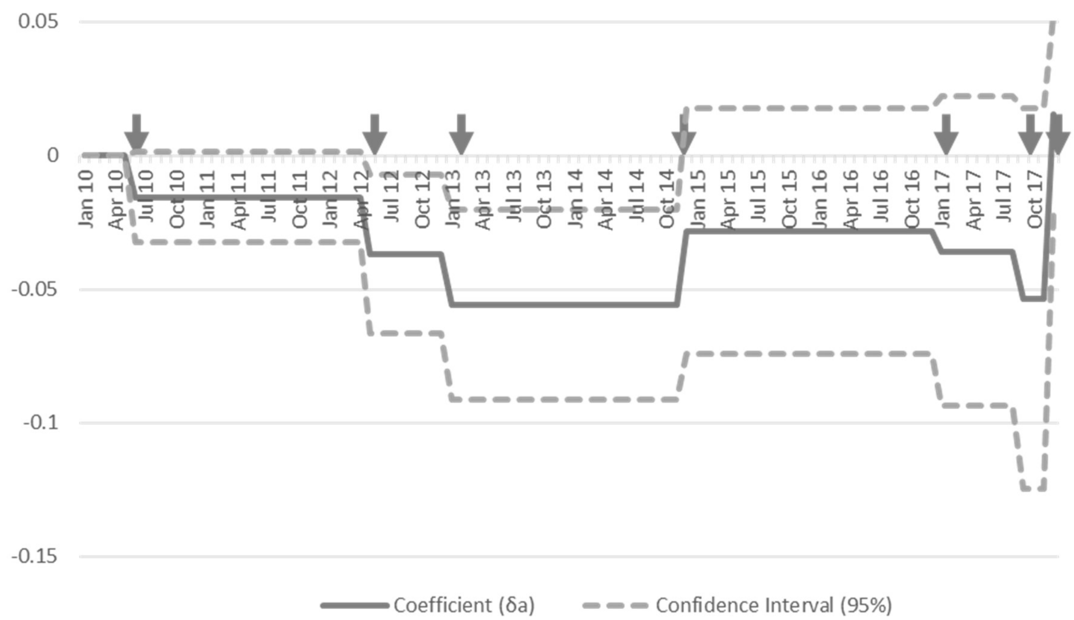
The key-indicator, the coefficient on the treatment effect term for the 55dB area, shows the expected negative sign and significance for the announcements in May 2012 (-3.85% for 55db) and January 2013 (about -3.2%). The corresponding treatment effects for the 60dB area are slightly less negative for these two announcements; in other words, considering both events separately, the May 2012 event shows stronger effects (for 55dB and 60dB). When both events are included together in the same regression, January 2013 has stronger effects for the 55dB noise pollution (3.1% vs. 4.9%) and the May 2012 event has the stronger effect for the case of 60dB. This implies that apartment prices react more strongly to the January 2013 announcement, by lowering prices more with the indefinite opening date of BER. But the opposite was true for the apartments in the noisier area (60dB) – the May 2012 announcement led to a greater reduction in the prices of apartments for those noisier dwellings.

Table 3 **Noise effect on rent prices for May 2012 and January 2013**

Dep. Variable: ln(rent/sqm)	(1) May12 55dB	(2) Jan13 55dB	(3) May12 60dB	(4) Jan13 60dB	(5) Both 55dB	(6) Both 60dB
N_n	-0.0194***	-0.0245***	-0.0397***	-0.0445***	-0.0219***	-0.0406***
	(0.0033)	(0.0033)	(0.0064)	(0.0064)	(0.0033)	(0.0035)
T_t (May 12)	0.0346***		0.0348***		0.0327***	0.0298***
	(0.0016)		(0.0017)		(0.0017)	(0.0017)
T_t (Jan 13)		0.0170***		0.0170***	0.0391***	0.0345***
		(0.0018)		(0.0018)	(0.0021)	(0.0021)
N_nT_t (May 12)	**-0.0385*** **		**-0.0337*** **		**-0.0311*** **	**-0.0240*** **
	(0.0037)		**(0.0051)**		**(0.0042)**	**(0.0056)**
N_nT_t (Jan 13)		**-0.0320*** **		**-0.0275*** **	**-0.0493*** **	**-0.0376*** **
		(0.0041)		**(0.0055)**	**(0.0046)**	**(0.0061)**
Additional controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	186,170	186,170	170,658	170,658	186,170	186,170
Number of grids	162	162	159	159	162	162
Time trends	Yes	Yes	Yes	Yes	Yes	Yes
Grid FE	Yes	Yes	Yes	Yes	Yes	Yes

*Standard errors clustered on grid level in parentheses. All included apartments have a maximum driving distance to Berlin-Tegel of 15 minutes; *** p<0.01, ** p<0.05, * p<0.1. Estimations based on equation (1). Source: RWI-GEO-RED.*

Figure 4 **Noise effect on logarithmic rent prices (all announcements – 55dB cutoff)**



All included apartments have a maximum driving distance to Berlin-Tegel of 15 minutes. Estimations based on equation (3a). Solid line illustrates the coefficients of the variables N_n for each of the estimated delay announcements. Source: RWI-GEO-RED.

Figure 4 (based on equation 3a) illustrates the effects we obtain from an estimation including all announcements in the 55dB area.[19] While the effect for the first minor announcement in June 2010

[19] The magnitude of each of the coefficients for the individual announcements is difficult to interpret and compare among each other. The respective value of the announcement dummy becomes one after the announcement was made and returns to zero after a new announcement was made. This definition ensures that only the respective announcement dummy captures the effect from the announcement. However, prior announcements may still affect rent prices after the next announcement.

remains insignificant, we obtain significant negative effects of announcements for May 2012 and the effect increases for January 2013 when the second substantial delay was announced without an announcement of a new planned opening. Once a new opening date was planned (in December 2014), the effects return to be insignificant. The results also remain insignificant for September 2017, which is not associated with a further delay announcement, but the implementation of the referendum on continuation of air-services at Tegel. These results imply that the two announcements used before are those that most notably impact housing prices.

Table 4 **Heterogeneity of Noise effects: Other noise, Apartment size, Local unemployment**

	(1)	(2)	(3)	(4)	(5)	(6)
	Other Noise		**Apartment Size**		**Neighborhood**	
Dep. Variable:	**May12**	**Jan13**	**May12**	**Jan13**	**May12**	**Jan13**
ln(rent/sqm)	**55dB**	**55dB**	**55dB**	**55dB**	**55dB**	**55dB**
N_n	-0.0209*	-0.0251**	-0.0172	-0.0212*	-0.0204*	-0.0246**
	(0.0114)	(0.0118)	(0.0110)	(0.0115)	(0.0105)	(0.0109)
T_t	0.0331***	0.0123**	0.0330***	0.0129**	0.0340***	0.0145**
	(0.0051)	(0.0057)	(0.0050)	(0.0055)	(0.0051)	(0.0056)
$\boldsymbol{N_n T_t\ (Treat_{nt})}$	**-0.0282****	**-0.0201**	**-0.0667*****	**-0.0579*****	**-0.0405*****	**-0.0320*****
	(0.0110)	**(0.0137)**	**(0.0123)**	**(0.0128)**	**(0.0106)**	**(0.0112)**
Low noise	0.0201***	0.0198***				
(other sources)	(0.0047)	(0.0047)				
Small apartments			0.0420***	0.0429***		
			(0.0044)	(0.0044)		
Low unemployment					0.0079	0.0084
					(0.0098)	(0.0105)
$\boldsymbol{N_n T_t}$**x low other noise**	**-0.0171***	**-0.0167***				
	(0.0091)	**(0.0092)**				
$\boldsymbol{N_n T_t}$**x**			**0.0498*****	**0.0485*****		
small apartments			**(0.0079)**	**(0.0081)**		
$\boldsymbol{N_n T_t}$**x**					**-0.0262***	**-0.0238**
low unemployment					**(0.0154)**	**(0.0154)**
Additional controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	186,170	186,170	186,170	186,170	186,170	186,170
R-squared	0.5161	0.5152	0.5197	0.5187	0.5149	0.5141
Number of grids	162	162	162	162	162	162
Time trends	Yes	Yes	Yes	Yes	Yes	Yes
Grid FE	Yes	Yes	Yes	Yes	Yes	Yes

*Standard errors clustered on grid level in parentheses. All included apartments have a maximum driving distance to Berlin-Tegel of 15 minutes; *** p<0.01, ** p<0.05, * p<0.1. Noise level (other sources), apartment size and unemployment rate split in two groups (low/high) at the median. Estimations based on equation (1). Source: RWI-GEO-RED.*

Heterogeneity – Noise Results

The general negative effect of the delay on apartments that are affected by aviation noise is well documented in the results presented above. Going more into detail, we test if the general effect of about -3% to -5% varies by characteristics of either the apartment or the neighborhood. Thereby, we test four hypotheses.

First, other sources of noise might be contaminating our measure of aircraft noise effects. Therefore, we control and test for other sources of noise (which we call "environmental noise"), assuming prices in quieter areas react more strongly to the remaining aviation noise. Bringing the environmental noise hypothesis into a testable setup, we define a dummy taking the value of 1 if environmental noise is below the median environmental noise, and 0 otherwise. Apartments with low environmental noise show an additional negative price reduction (shown in the first two columns of Table 4), summing up to a total effect of 3.7% to 4.5%.

Second, we split the sample by apartment size (with results in columns 3 and 4 of Table 4). Regarding the heterogeneity by apartment size, we split the sample into below and above median groupings. Here, the announcement effect increases to the range of -6% to -7% for apartments with above-median size, while the remaining effect for small apartments is only about 1% to 2%. This result seems plausible as tenants of larger apartments (more likely for families) tend to i) spend more time at home, ii) stay longer in the rented apartments and iii) have higher preferences for quiet residential areas than other groups.

Third, we test whether there is heterogeneity regarding the economic neighborhood characteristic, which is the unemployment rate. We distinguish between above- and below-median unemployment rates. In general, the announcement effect is about 3% to 4% for neighborhoods with above-median unemployment rate. Results are shown in columns 5 and 6 of Table 4. Apartments in neighborhoods with low unemployment have an additional effect of about 2% (which is significant for the May 2012 announcement but insignificant for the January 2013 announcement).

Finally, we consider heterogeneity with respect to apartment prices (Table 5). For this, we run a quantile regression approach in the noise effects model. We find that higher priced apartments experience a larger noise discount. Assuming higher priced apartments are also of higher quality, this implies that renters of higher quality apartments demonstrate a greater willingness to pay for noise reduction than renters of lower quality apartments.

Table 5 Quantile Regressions of Noise Impacts

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Variable:		**May12 Announcement**			**Jan 13 Announcement**	
ln(rent/sqm)	**p25**	**p50**	**p75**	**p25**	**p50**	**p75**
N_n (55dB)	-0.0107***	-0.0168***	-0.0230***	-0.0134***	-0.0213***	-0.0293***
	(0.0039)	(0.0029)	(0.0038)	(0.0039)	(0.0030)	(0.0038)
T_t	0.0363***	0.0337***	0.0311***	0.0143***	0.0142***	0.0141***
	(0.0024)	(0.0018)	(0.0023)	(0.0026)	(0.0020)	(0.0025)
$\boldsymbol{N_n T_t \ (Treat_{nt})}$	**-0.0308*** **	**-0.0382*** **	**-0.0455*** **	**-0.0148*** **	**-0.0310*** **	**-0.0472*** **
	(0.0043)	**(0.0032)**	**(0.0042)**	**(0.0047)**	**(0.0035)**	**(0.0045)**
Additional controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	186,170	186,170	186,170	186,170	186,170	186,170
R-squared		0.5148			0.5140	
Number of grids		162			162	
Time trends		Yes			Yes	
Grid FE		Yes			Yes	

*Standard errors clustered on grid level in parentheses. All included apartments have a maximum driving distance to Berlin-Tegel of 15 minutes; *** p<0.01, ** p<0.05, * p<0.1. Estimations based on equation (1). Source: RWI-GEO-RED.*

Drive Time

As described in the previous sections, airports are not only linked to negative effects on housing prices (via noise pollution) but also to positive amenities, e.g. better connectivity and/or job opportunities. Therefore, estimations in Table 6 focus on the rent price effects for apartments that benefit from being located within a short driving time to the airport, but simultaneously do not suffer from noise pollution. This sample covers all listed apartments in Berlin and those with a driving time to Berlin-Tegel below 15 minutes and below 20 minutes as two alternative treatment groups. Apartments with longer driving times than 20 minutes are the control group, and any apartments with noise pollution near Tegel airport are not included in the regressions here to avoid biased estimates.[20]

Table 6 **Drivetime effects on rent prices**

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Variable: ln(rent/sqm)	**May12 15 min**	**Jan13 15 min**	**May12 20 min**	**Jan13 20 min**	**Both 15min**	**Both 20min**
$\widetilde{N}_d$	-0.0331**	-0.0304**	-0.0184*	-0.0160	-0.0322**	-0.0178*
	(0.0152)	(0.0153)	(0.0105)	(0.0106)	(0.0151)	(0.0105)
T_t (May 12)	0.0084***		0.0030		0.0111***	0.0063**
	(0.0031)		(0.0035)		(0.0030)	(0.0031)
T_t (Jan 13)		-0.0054		-0.0087*	0.0027	-0.0032
		(0.0036)		(0.0045)	(0.0044)	(0.0053)
$\boldsymbol{\widetilde{N}_d T_t}$ **(May 12)**	**0.0187*** **		**0.0205*** **		**0.0159*** **	**0.0180*** **
	(0.0067)		**(0.0057)**		**(0.0060)**	**(0.0051)**
$\boldsymbol{\widetilde{N}_d T_t}$ **(Jan 13)**		**0.0129***		**0.0132** **	**0.0222** **	**0.0234*** **
		(0.0077)		**(0.0065)**	**(0.0093)**	**(0.0079)**
Additional controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	690,826	690,826	690,826	690,826	690,826	690,826
Number of grids	741	741	741	741	741	741
Time trends	Yes	Yes	Yes	Yes	Yes	Yes
Grid FE	Yes	Yes	Yes	Yes	Yes	Yes

*Note: ***, **, * denote significance at the 1 %-, 5 %- and 10 %-level. Robust standard errors clustered on 1*1km-grid level in parentheses. Estimations based on equation (2). Source: RWI-GEO-RED.*

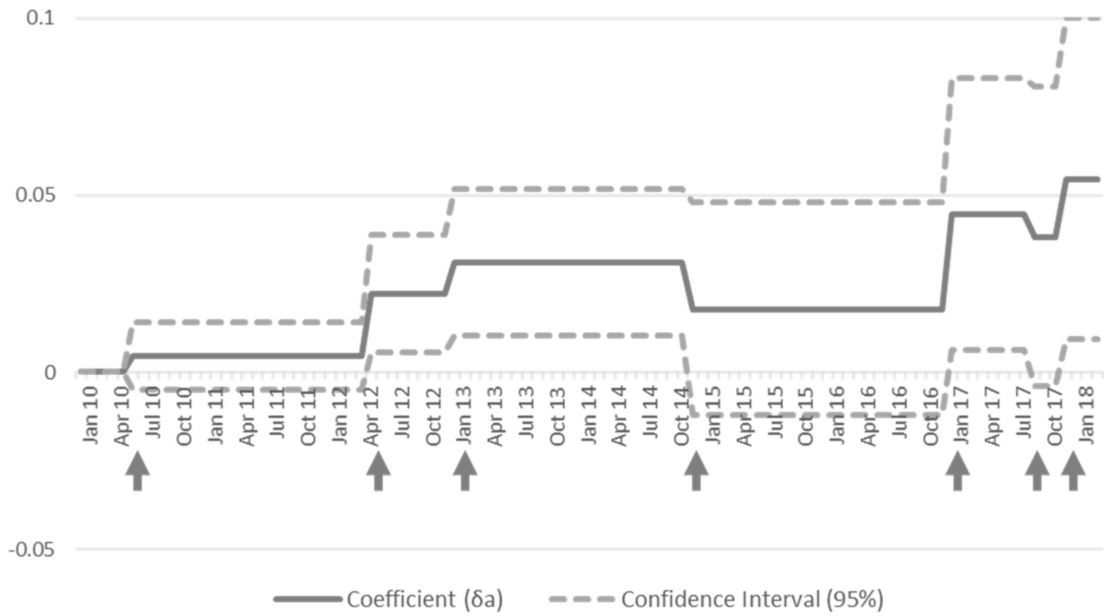
In Table 6 we show estimation results for the rental price effects of the two major announcements in May 2012 (column 1 and 2) and January 2013 (column 3 and 4), and combine both effects in a joint estimation (column 5 and 6). In general, we observe the expected positive effect of the announcements for apartments within short driving times. The effects remain quite stable in size and significance for both thresholds (15 and 20 minutes), while the effects for the first announcement in May 2012 are slightly larger (1.9% to 2.1%) than those effects for January 2013 (1.3%). Pooling the data for both announcements also leads to significance, with both coefficients between 1.6% and 2.4%.

The chosen estimation strategy requires a threshold for the definition of proximity, which might be viewed as arbitrary to some extent. Allowing for our estimation to be less sensitive to the definition of the threshold, we also conduct the estimation in a “donut-regression”, which drops observations with a driving time between 15 minutes and 30 minutes (and respectively, between 20 minutes and 30 minutes). As the control group is defined by a driving time of more than 30 minutes, dwellings do not change from treatment to control group between this donut analysis and our prior analysis. The results (presented in Appendix Table A2) do not substantively change.

To obtain comparable results, we focus on presenting the joint estimation of all announcements (following equation 3b).[21] In Figure 5 we graphically depict the drive time regression coefficients over time for all announcements. According to the prior estimations focusing on May 2012 and January 2013, coefficients for both events also become significant when we include all announcements. In line with the prior results for the noise effects, the drive time effects also become insignificant in December 2014 when a new opening date is announced. Regarding the drive time, the later announcements and the referendum in September 2017 seem to affect rent prices.

[20] Note that our data on noise pollution are truncated on the left side of the noise distribution at a level of 55dB. We cannot identify apartments with noise pollution below this threshold.
[21] Since these estimation tables of equation 2 for each announcement separately are quite large, they are available from the authors upon request.

Figure 5 **Drivetime effect on rent prices (all announcements – 20 Minutes cutoff)**



Apartments with noise pollution are excluded from the regression. Estimations based on equation (3b). Solid line illustrates the coefficients of the variables N_d for each of the estimated delay announcements. Source: RWI-GEO-RED.

Heterogeneity – Drive Time Results

We also consider heterogeneity in the drive time estimations. We expect employed inhabitants to benefit more from the short drive time to the airport (e.g., people employed at the airport, or those using the airport regularly for business reasons). As we do not have information on individual employment status of tenants (or apartment seekers) we apply the local unemployment rate in the neighborhood as a proxy, splitting the sample in the grids into below and above the median unemployment rate.

In columns 1 and 2 of Table 7, the results must be considered with respect to two separate effects. We observe the basic positive effect of the announcements (varying between 3.3% and 3.6%), but for apartments in neighborhoods with low unemployment the additional effects are -2.7% (May 2012) and -3.9% (January 2013). In sum, we obtain roughly zero effects for neighborhoods with lower unemployment. However, as we are not able to observe individual employment status, the neighborhood unemployment might be misleading. Higher unemployment rates are rather an indicator for inhabitants working in lower-skilled jobs. From this perspective, it again makes sense that such neighborhoods with lower-skilled jobs would benefit from the continued operations of the airport. Such low-skilled jobs (especially in the service sector) are frequently found at airports and Tegel airport had about 7 000 employees.

We also subdivide the drive time analysis according to the size of the apartments (Table 7, columns 3 and 4). Here, the results show that the positive effect exists especially for larger apartments. For the smaller ones, which are also included separately in the interaction, the results tend toward zero. Finally, in Table 8, we estimate quantile regressions using the drive time treatment effect cutoffs of 20 minutes. For both treatment effects, May 2012 and January 2013, the effects are positive and statistically significant. The treatment effects are smaller for the lower quantiles and increase for the higher quantiles. This implies that higher priced apartments near the airport, after a delay in the closure, have higher price changes than lower priced apartments within similar driving distances.

Perhaps more residents desiring “nicer” apartments value airport proximity for travelling and employment opportunities.

Table 7 Heterogeneity of Drivetime effects
Apartment size, Local Unemployment, by Announcement Date

	(1)	(2)	(3)	(4)
Dep. Variable:	**May 12**	**Jan13**	**May 12**	**Jan13**
ln(rent/sqm)	**20 min**	**20 min**	**20 min**	**20 min**
$\widetilde{N_d}$	-0.0184*	-0.0167	-0.0193*	-0.0168
	(0.0102)	(0.0102)	(0.0105)	(0.0105)
T_t	0.0039	-0.0077*	0.0033	-0.0079*
	(0.0034)	(0.0046)	(0.0034)	(0.0044)
$\boldsymbol{\widetilde{N_d}T_t}$	**0.0330*** **	**0.0360*** **	**0.0266*** **	**0.0168** **
	(0.0070)	**(0.0087)**	**(0.0067)**	**(0.0075)**
Small apartments			0.0533***	0.0518***
			(0.0037)	(0.0036)
Low unemployment rate	0.0102*	0.0108**		
	(0.0055)	(0.0053)		
$\boldsymbol{\widetilde{N_d}T_t}$ **x**	-0.0273***	-0.0396***		
low unemployment rate	(0.0078)	(0.0085)		
$\boldsymbol{N_d T_t}$ **x small apartments**			-0.0152**	-0.0108*
			(0.0060)	(0.0061)
Additional controls	Yes	Yes	Yes	Yes
Observations	690,826	690,826	690,826	690,826
R-squared	0.4864	0.4864	0.4909	0.4906
Number of grids	741	741	741	741
Time trends	Yes	Yes	Yes	Yes
Grid FE	Yes	Yes	Yes	Yes

*Note: ***, **, * denote significance at the 1 %-, 5 %- and 10 %-level. Robust standard errors clustered on 1*1km-grid level in parentheses. Estimations based on equation (2). Noise level (other sources), apartment size and unemployment rate split in two groups (low/high) at the median. Source: RWI-GEO-RED.*

Table 8 Quantile Regressions of Drive times

	1	2	3	4	5	6
		May 12 Announcement			**Jan 13 Announcement**	
Dep. Variable:		**20 min**			**20 min**	
ln(rent/sqm)	**p25**	**p50**	**p75**	**p25**	**p50**	**p75**
$\widetilde{N_d}$	-0.0185***	-0.0184***	-0.0184***	-0.0171***	-0.0159***	-0.0148***
	(0.0026)	(0.0019)	(0.0024)	(0.0025)	(0.0019)	(0.0024)
T_t	0.0105***	0.0030***	-0.0045***	-0.0027*	-0.0088***	-0.0148***
	(0.0013)	(0.0010)	(0.0013)	(0.0014)	(0.0011)	(0.0014)
$\boldsymbol{\widetilde{N_d}T_t}$	**0.0136*** **	**0.0206*** **	**0.0275*** **	**0.0062*** **	**0.0133*** **	**0.0202*** **
	(0.0020)	**(0.0015)**	**(0.0019)**	**(0.0021)**	**(0.0016)**	**(0.0020)**
Additional controls		Yes			Yes	
Observations		690,826			690,826	
R-squared		0.486			0.4858	
Number of grids		741			741	
Time trends		Yes			Yes	
Grid FE		Yes			Yes	

*Note: ***, **, * denote significance at the 1 %-, 5 %- and 10 %-level. Robust standard errors clustered on 1*1km-grid level in parentheses. Source: RWI-GEO-RED.*

Overall effects

As outlined above, the unique setting with Tegel allows us to identify effects from the short drivetime and the noise pollution at the same time since they come into play simultaneously. The analysis requires three geographically separated treatment group defining i) dwellings only affected by noise but not by proximity ($\widetilde{N_n}$), ii) dwellings only affected by proximity but not by noise ($\widetilde{N_d}$) and iii) dwellings affected by both – noise and proximity ($N_n N_d$). As there is no geographical overlap of the three coefficients from the treatment variables, ($\widetilde{N_n} T_t$, $\widetilde{N_d} T_t$ and $\boldsymbol{Treat_{ndt}}$) can be interpreted separately.

The corresponding results in Table 9 focus on the treatment definition of 55dB (for both proximity definitions, 15 and 20 minutes, as well as both major announcements, May 2012 and January 2013). Results for 60dB can be found in the appendix (Table A3). All specifications lead to similar results.

The announcements of ongoing operations at Tegel airport positively affect those dwellings in proximity to the airport (not exposed to noise pollution). The effects range between 1.4% and 2.4%. Those dwellings exposed to the noise but not located in proximity to the airport show negative effects of the announcements compared to completely unaffected dwellings. Regarding the effect size of about 4% to 6%, the effect becomes stronger than in the prior setting, which only measures the effect of nose-pollution within a driving time of up to 15 minutes. Nevertheless, focusing on those dwellings affected by noise and proximity shows no clear effect of the announcements relative to the unaffected dwellings. In general, the coefficients show negative signs but do not become significant in any specification. From that perspective, we do clearly find airport effects regarding noise and proximity, but once both effects occur together, the effects cancel each other out.

Table 9 **Noise and drivetime effects on rent prices**

Dep. Variable: ln(rent/sqm)	(1) **May 12** **55dB/15 minutes**	(2) **Jan 13** **55dB/15 minutes**	(3) **May 12** **55dB/20 minutes**	(4) **Jan 13** **55dB/20 minutes**
$\widetilde{N_n}$	-0.0192	-0.0248	-0.0256**	-0.0294***
	(0.0197)	(0.0189)	(0.0125)	(0.0111)
$\widetilde{N_d}$	0.0191*	0.0232**	-0.0119	-0.0093
	(0.0114)	(0.0117)	(0.0086)	(0.0087)
T_t	0.0067*	-0.0044	0.0039	-0.0081*
	(0.0034)	(0.0044)	(0.0035)	(0.0045)
$\boldsymbol{\widetilde{N_d} T_t}$	**0.0236*** **	**0.0176** **	**0.0204*** **	**0.0135** **
	(0.0070)	**(0.0081)**	**(0.0057)**	**(0.0065)**
$\boldsymbol{\widetilde{N_n} T_t}$	**-0.0565*** **	**-0.0505** **	**-0.0468** **	**-0.0392** **
	(0.0216)	**(0.0216)**	**(0.0209)**	**(0.0199)**
$\boldsymbol{N_d N_n T_t}$ $(\boldsymbol{Treat_{ndt}})$	**-0.0134**	**-0.0101**	**-0.0057**	**-0.0029**
	(0.0095)	**(0.0103)**	**(0.0078)**	**(0.0080)**
Additional controls	Yes	Yes	Yes	Yes
Observations	569,266	569,266	747,837	747,837
R-squared	0.5022	0.5019	0.4895	0.4892
Number of grids	715	715	774	774
Time trends	Yes	Yes	Yes	Yes
Grid FE	Yes	Yes	Yes	Yes

*Note: ***, **, * denote significance at the 1 %-, 5 %- and 10 %-level. Robust standard errors clustered on 1*1km-grid level in parentheses. Estimations based on equation (4). Source: RWI-GEO-RED.*

Conclusion

We consider the impacts of the exogenous and unanticipated shocks through noise and connectivity associated with the continued operation of Tegel airport. Since the closing of Tegel was planned to occur at the same time as the opening of the new airport (BER), we use the delay announcements for the BER opening as part of our approach to generate causal estimates. We use a diff-in-diff approach as our identification strategy and rely on rental asking price data for Berlin (Germany) apartments covering the period of 2010-2017. There have been at least seven delay announcements for the opening of BER and one referendum considering whether Tegel should be closed at all. Our main estimations focus on the major announcements in May 2012 (which was very close to the opening planned for one month later) and January 2013 (which did not announce a new scheduled opening date). We have very good data and a strong empirical framework to consider these delay announcements as exogeneous shocks, as they were not anticipated by any involved actor.

We find that noise at levels above thresholds of 55dB/60dB reduces rental prices by approximately 2% to 5%, depending on the level of noise chosen as the threshold. Further, incorporating all announcements into one regression shows that later announcements have negligible effects on rent prices (tending to be in the same direction but remaining insignificant). We also examine the potential benefits from proximity due to continued operations at Tegel, and we find a positive effect of approximately 1% to 3%, depending on the exact location of the properties chosen as the drive time threshold.

These results confirm the findings in the airport noise and access literature that higher noise lowers property prices, controlling for proximity, but enhanced proximity leads to higher property prices, if the property is not affected by noise. We also test for heterogeneity in our results, observing the effects of noise pollution are strongest in areas where other noise pollution is not present. Additionally, the noise effects are stronger for larger dwellings and in neighborhoods with low unemployment. Higher priced apartments have a larger noise discount than lower priced apartments, implying a greater willingness to pay for noise avoidance in “nicer” apartments (assuming price is correlated with quality). On the other hand, higher priced apartments have larger price effects for proximity, implying that the effects for well-paying jobs and travel opportunities are larger than for lower paying jobs.

Arguably, one of the strongest contributions of our analyses is that, due to the unique setting in Tegel, prices are influenced by positive and negative effects simultaneously. Thus, we can consider both effects – noise and proximity – into one analysis and credibly evaluate an overall effect of airport proximity. While the individual airport effects (noise and proximity) show the expected coefficients, neither of the two effects dominate when both are considered simultaneously. Dwellings that are exposed to airport noise but benefit from proximity at the same time, do not show price reactions from the delay compared with non-affected dwellings. As we can detect each effect when they occur alone, we conclude that both effects cancel each other out.

Furthermore, our focus on the noise and proximity effects due to the closure of Tegel, opposed to considering expected noise and job creation from opening BER, provides tangible information for our quasi-experiment. The noise and job opportunities for residents near Tegel are well-known, while near BER these are only based on forecasts. Therefore, a delay announcement for the closure of Tegel can generate more reliable estimates of the impacts on property values than an estimate of the effects of delays in opening of BER on property values near that new airport.

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Appendix

Table A.1: Summary statistics on characteristics for rent objects

Variable	Obs	Mean	Std. Dev.	Min	Max
Ln(rent/sqm)	695 267	2.01	0.29	1.27	2.87
Month	695 267	635.88	23.13	600	683
Age	695 267	44.90	44.41	0	460
Age²	695 267	3988.45	5326.91	0	211600
Age UNKNOWN	695 267	0.30	0.46	0	1
Floor size	695 267	74.11	28.30	28.52	196
Floor	695 267	1.84	3.17	-4	16
Floor unknown	695 267	0.14	0.35	0	1
Number of floors	695 267	3.21	3.03	0	15
Number of floors unknown	695 267	0.33	0.47	0	1
Number of rooms	695 267	2.43	1.20	0	8
Number of rooms UNKOWN	695 267	0.12	0.32	0	1
Balcony	695 267	0.67	0.47	0	1
Balcony unknown	695 267	0.05	0.22	0	1
Kitchen	695 267	0.44	0.50	0	1
kitchen unknown	695 267	0.14	0.35	0	1
Garden	695 267	0.12	0.32	0	1
Garden unknown	695 267	0.25	0.43	0	1
Cellar	695 267	0.50	0.50	0	1
Cellar unknown	695 267	0.06	0.25	0	1
Quality of apartment					
Unknown	695 267	0.55	0.50		
Simple	695 267	0.01	0.10	0	1
Normal	695 267	0.21	0.41	0	1
Sophisticated	695 267	0.20	0.40	0	1
Deluxe	695 267	0.03	0.16	0	1
Heating type					
Cogeneration/combined heat and power pl	695 267	0.00	0.04	0	1
Electric	695 267	0.00	0.01	0	1
Self-contained central	695 267	0.12	0.32	0	1
District	695 267	0.03	0.17	0	1
Floor heating	695 267	0.01	0.09	0	1
Gas heating	695 267	0.01	0.09	0	1
Wood pellet	695 267	0.00	0.01	0	1
Night storage	695 267	0.00	0.02	0	1
by stove	695 267	0.00	0.04	0	1
Oil heating	695 267	0.00	0.05	0	1
Solar	695 267	0.00	0.01	0	1
Thermal heat pump	695 267	0.00	0.01	0	1
Central heating	695 267	0.63	0.48	0	1
Unknown	695 267	0.20	0.40	0	1
Quality of house					
First occupancy	695 267	0.05	0.21	0	1
First occ. after reconstruction	695 267	0.08	0.27	0	1
Like new	695 267	0.05	0.21	0	1
Reconstructed	695 267	0.09	0.29	0	1
Modernized	695 267	0.06	0.24	0	1
Completely renovated	695 267	0.11	0.31	0	1
Well kempt	695 267	0.21	0.41	0	1
Needs renovation	695 267	0.01	0.11	0	1
By arrangement	695 267	0.01	0.09	0	1
Dilapidated	695 267	0.00	0.00	0	1
Unknown	695 267	0.32	0.47	0	1
Houses in neighborhood	695 267	632.24	222.69	1	1333
Persons in neighborhood	695 267	34010.30	5833.93	19265	72899
Households in neighborhood	695 267	5821.50	3524.60	1	14685

Table A2: Drivetime effects on rent prices – Donut-regression

Dep. Variable: ln(rent/sqm)	(1) May 12 15 minutes	(2) Jan 13 15 minutes	(3) May 12 20 minutes	(4) Jan 13 20 minutes
T_t	0.0051	-0.0066	-0.0007	-0.0118*
	(0.0058)	(0.0063)	(0.0059)	(0.0062)
$\boldsymbol{\widetilde{N_d} T_t\ (Treat_{idt})}$	**0.0308*** **	**0.0228*** **	**0.0271*** **	**0.0164** **
	(0.0077)	**(0.0081)**	**(0.0069)**	**(0.0076)**
Additional controls	Yes	Yes	Yes	Yes
Observations	295,396	295,396	451,551	451,551
R-squared	0.5042	0.5035	0.4809	0.4804
Number of grid	409	409	558	558
Time trends	Yes	Yes	Yes	Yes
Grid FE	Yes	Yes	Yes	Yes

*Note: ***, **, * denote significance at the 1 %-, 5 %- and 10 %-level. Robust standard errors clustered on 1*1km-grid level in parentheses. Estimations based on difference-in-differences from equation (2). $Since\ \widetilde{N_d}$ does not vary within a 1*1km grid, once a subset of drivetimes (from either 15 or 20 mitues to 30 minutes) is excludd from the regression, $\widetilde{N_d}$ is omitted because of multicollinearity with the fix effects on grid level. Source: RWI-GEO-RED.*

Table A3: Noise and drivetime effects on rent prices – 60 dB

Dep. Variable: ln(rent/sqm)	(1) **May 12 60dB/15 minutes**	(2) **Jan 13 60dB/15 minutes**	(3) **May 12 60dB/20 minutes**	(4) **Jan 13 60dB/20 minutes**
$\widetilde{N_n}$	0.0538***	0.0446**	-0.0330	-0.0356
	(0.0170)	(0.0180)	(0.0234)	(0.0238)
$\widetilde{N_d}$	0.0346*	0.0379*	-0.0156	-0.0131
	(0.0191)	(0.0196)	(0.0100)	(0.0101)
T_t	0.0065*	-0.0046	0.0037	-0.0081*
	(0.0034)	(0.0044)	(0.0035)	(0.0045)
$\widetilde{N_d} T_t$	**0.0241*** **	**0.0179** **	**0.0206*** **	**0.0134** **
	(0.0070)	**(0.0081)**	**(0.0057)**	**(0.0065)**
$\widetilde{N_n} T_t$	**-0.0551*** **	**-0.0451** **	**-0.0405*** **	**-0.0360** **
	(0.0181)	**(0.0212)**	**(0.0156)**	**(0.0153)**
$N_d N_n T_t\ (\boldsymbol{Treat_{ndt}})$	**-0.0106**	**-0.0071**	**-0.0044**	**-0.0064**
	(0.0123)	(0.0150)	(0.0098)	(0.0102)
Additional controls	Yes	Yes	Yes	Yes
Observations	551,763	551,763	720,572	720,572
R-squared	0.5009	0.5006	0.4876	0.4873
Number of grid	706	706	768	768
Time trends	Yes	Yes	Yes	Yes
Grid FE	Yes	Yes	Yes	Yes

*Note: ***, **, * denote significance at the 1 %-, 5 %- and 10 %-level. Robust standard errors clustered on 1*1km-grid level in parentheses. Estimations based on difference-in-differences from equation (2). Source: RWI-GEO-RED.*