sustainability

MDPI

Article

Investigating the Impact of Airport Noise and Land Use Restrictions on House Prices: Evidence from Selected Regional Airports in Poland

Jacek Batóg [1], Iwona Foryś [1], Radosław Gaca [2], Michał Głuszak [3,*] and Jan Konowalczuk [4]

[1] Department of Econometrics and Statistics, University of Szczecin, 70-453 Szczecin, Poland; jacek.batog@usz.edu.pl (J.B.); iwona.forys@usz.edu.pl (I.F.)
[2] Kancelaria Rzeczoznawcy Majątkowego Radosław Gaca, 85-005 Bydgoszcz, Poland; rgaca@poczta.onet.pl
[3] Department of Real Estate and Investment Economics, Cracow University of Economics, 31-510 Krakow, Poland
[4] Department of Investment and Real Estate, University of Economics in Katowice, 40-287 Katowice, Poland; jan.konowalczuk@ue.katowice.pl
* Correspondence: gluszakm@uek.krakow.pl; Tel.: +48-12-293-7482

Received: 2 December 2018; Accepted: 12 January 2019; Published: 15 January 2019

Abstract: In this paper, we investigate the influence of airport operation on property prices. In this research, we apply spatial hedonic regression and a difference-in-differences approach to address the introduction of new land use restrictions on property prices. We use data on housing transactions from two housing submarkets around regional airports in Poland. The results suggest that the introduction of land use restrictions impacts property prices. In general, as expected, more rigid restrictions translate into higher discounts in property prices. This research contributes to the limited knowledge on the impact of the introduction of land use restrictions on property prices, as most previous papers have focused solely on the impact of noise. These findings must be treated with caution, as some estimates were not statistically significant, mainly due to limited sample size. The research has important policy implications. Growing airports in Poland face tensions between economic and environmental sustainability. Currently, airports in Poland are obliged to limit their environmental impact by creating limited use areas related to the aircraft related noise while being responsible for property value loss related to these restrictions. As a consequence, most regional airports face significant compensations to property owners.

Keywords: airport noise; house prices; land use; hedonic model; negative externalities

---

1. Introduction

Airport operation generates several externalities, some of which manifest on the property market—both negative (air pollution and noise, catastrophic risk, view disturbance) and positive (job availability, well-developed infrastructure, and public transit) [1]. Although the evidence shows there is a link between airports and urban development [2], airport operation can have detrimental consequences for neighbourhoods in proximity. One of the most profound negative externalities is noise pollution [3]. From an urban economic perspective, the net effect of airport proximity manifests in real estate prices. According to numerous empirical studies coming from different countries (although mostly from the US) airport noise has a significant negative impact on house prices. While some other types of land use limitations can decrease residential housing supply and drive up property prices, the final effects are strongly dependent on the demographic features of the possible buyers [4].

In many cases, there is a strong tension between economic sustainability (long-term economic growth, stable employment, infrastructure development), and environmental sustainability (limitation of negative externalities—noise, pollution) of the airport's operation. As a consequence, airport growth influences local planning and is often converted into restrictive local zoning plans, limiting potential development on the affected area in order to eliminate negative externalities. In Poland according to the Environmental Protection Law [5], Limited Land Use Areas (LLUAs) can be created around airports. Until 2018 only selected airports had established limited land use areas (LLUA). During the study period (2008–2016) LLUAs were introduced around: the Warsaw Modlin airport in NowyDwor Mazowiecki, the Poznan-Lawica airport in Poznan, the Warsaw Chopin airport in Warsaw, the Krakow-Balice airport, the Wrocław-Starachowice airport, and the Katowice airport in Pyrzowice. Introduction of both local zoning plan and LLUA can influence house prices. This negative effect can be both direct and indirect. The direct effect is linked to the restriction that decreases the development potential of properties within the area affected. The indirect effect comes from public disclosure of airport noise and increased awareness of the general public (and house buyers) about the negative externalities generated by the airport. It can be argued that higher awareness can later translate into revealed preferences on the housing market and, as a consequence, is discounted in residential prices.

The paper attempts to assess the influence of airports on property prices, and disentangle the effects of (i) airport noise and (ii) land use restrictions (introduced via LLUAs). Negative airport externalities—mostly noise or pollution—decrease both residential satisfaction in the area affected and property values. Additionally, restrictions on land use (for example, related to residential development), a lower density of development, and additional technical regulations (sound isolation requirements) may have a detrimental effect on property prices.

The problem arises when aircraft noise nuisance and imposed land use restrictions overlap. While the former effect was covered by many articles, the later effect is relatively understudied. Moreover, the majority of empirical evidence comes from mature economies (mostly the US, and Western Europe). Thus, it is not sure whether the findings fully apply to other urban and economic settings. It can be argued that in an emerging market, given (i) relatively low environmental and legal awareness of house buyers, and (ii) the low transparency and less efficient market, the negative effect of the airport operation might not be fully discounted in property values. The article aims to address these concerns and fill the gap in the literature regarding relations between airport operation and the property market.

In order to address the research problem, we studied the housing market around two regional airports in Poland: Pyrzowice, and Poznan-Lawica. We use spatial hedonic regression to assess the joint effect of airport noise on property prices. The analysis utilizes the data on housing transactions within the chosen research area around the airport. Data on the sale of houses were obtained from notarial acts gathered in the Real Estate Cadastre and the National Geodetic and Cartographic Resources. To address the problem of endogeneity, and to assess the causal effect of the introduction of an LLUA on house prices we use the Difference-In-Differences (DiD) approach.

The paper is organized as follows. The following section reflects on previous research, listing major findings from other empirical studies addressing the impact of airport operation on property values. The Section Materials and Methods discusses the methodology of the research, comparing study areas, describing datasets, and explaining the econometric approach. In the Results and Discussion sections, we describe major findings of our empirical investigation, as well as we discuss the limitation of the results. The last section presents a summary of the paper.

2. Previous Research

The results of empirical research concerning the impact of airport operation on property prices (both residential and commercial) are well documented in the economic literature. Since the 1960s several empirical studies have attempted to address the problem using various econometric strategies. The mainstream of empirical research was based on a hedonic framework, as discussed by Freeman, Herriges, and Kling [6] and Nelson [7]. In recent years modified with the growing popularity of spatial econometric methods, fostered by the increasing awareness of the problem of spatial dependence and data availability issues [8]. It is safe to say that the majority of the economic research focused on aircraft noise problem, mainly its relation to property values.

The influence of burdensome neighbourhood and noise on real estate prices were identified and quantified by many authors in different datasets, using different methods as well as for different localisations. Some sources of the results are presented in Table 1 (related to road and rail traffic) and in Table 2 (connected with airport noise). Four main group methods are mostly used for this purpose: (i) models based on price indices [9], (ii) hedonic models, including spatial hedonic regression models [10,11], (iii) counterfactual models, for instance, difference-in-difference [12], and (iv) stated preference methods [9]. Some authors point out that misspecification of the hedonic price function can seriously undermine its ability to estimate economic values accurately. One of the suggested solutions is related to adding spatial effects or use of Difference-in-Differences approach [13].

Table 1. Selected papers on the impact of road and rail noise on property prices.

No.	Authors	Article Title	Purpose/Conclusions
1	Bateman I., Day B., Lake I. and Lovett A.	The Effect of Road Traffic on Residential Property Values: A Literature Review and Hedonic Pricing Study	The authors quantified how physical factors associated with a new road affect the prices of properties based in Glasgow on a sample of over 3500 properties. They found that property prices were depressed by 0.20% for each decibel increase in road noise.
2	Chernobai E., Reibel M. and Carey M.	Nonlinear Spatial and Temporal Effects of Highway Construction on House Prices	There was a conclusion drawn, based on a spline hedonic model, about lack of efficiency of the real estate market when the information about the building of the new highway was announced.
3	Theebe M.	Planes, Trains, and Automobiles: The Impact of Traffic Noise on House Prices	The author, using spatial autocorrelation models, proved the influence of communication noise on real estate prices changes and found that this relationship is non-linear.
4	Wilhelmsson M.	The impact of traffic noise on the values of single-family houses	Traffic noise pollution was found to had had a substantial negative effect on housing values. Single-family houses located in a Stockholm suburb, near a road where the noise was loud, were sold with a total discount of 30%.
5	Diao M., Qin Y. and Sing T.	Negative Externalities of Rail Noise and Housing Values: Evidence from the cessation of Railway Operations in Singapore	The authors found that average prices for houses located within a 400-m boundary from railway lines increased by 3.5% relative to the prices for houses located outside the boundary after the removal of train noise externalities had been announced. They discovered that housing prices in the affected area increase by 13.7% on average in the post-cessation period.

Source: Own study [14–18].

Stated-preference methods are based on surveys, interviews or quasi-experiments, which allow respondents to express their willingness to pay for environmental improvements. In most cases, the received results are not robust for a change of assumptions as well as for different research subsamples. The applied economic research addressed the problem of negative externalities of airport operations using different econometric techniques, for different types of real estate—land, commercial property, and residential property. The studies were conducted in different periods, as well as for markets characterized by different size.

In the recent two decades, several empirical studies have addressed the problem of aircraft noise on property prices [10,19–25]. One of the last studies suggested that aircraft noise have a more profound negative effect on house prices than other types of noise—road and rail noise [3,26]. Most of the research agrees that airport noise negatively affects property prices. The evidence based on US data [21] suggests that the effect of airport noise is related to the type of function of property. The latter finding was confirmed in European studies [1,27]. Results seem to suggest that the negative impact of the location of airports is particularly noticeable for residential and recreational properties, whereas for commercial properties the negative effect is compensated by benefits arising from airport proximity [28].

Selection of research papers on the nexus between airport noise and real estate prices is presented in the table (Table 2).

Table 2. Selected papers on the impact of airport noise on property prices.

No.	Authors	Article Title	Purpose/Conclusions
1	Rahmatian M. and Cockerill L.	Airport noise and residential housing valuation in southern California: A hedonic pricing approach	Individuals consider airport proximity and airport flight patterns in their housing purchases. There exist two distinct measurable price gradients that distinguish large airports from small airports. Also, homes located under the flight path of a large airport have a price gradient that is significantly larger than homes located under the flight path of a small airport.
2	McMillen D.	Airport Expansions and Property Values: The Case of Chicago O'Hare Airport	Quieter aircraft in the Chicago O'Hare Airport have allowed the airport to expand without causing local property values to drop. House prices may even rise after addition of new runways.
3	Suksmith P. and Nitivattananon V.	Aviation Impacts on Property Values and Management: The Case of Suvarnabhumi International Airport	A significant negative effect of aircraft noise and air pollution on property prices in the case of Thailand's Suvarnabhumi Airport. Improvement of the compensation model is needed.
5	Feitelson E., Hurd R. and Mudge R.	The Impact of Airport Noise on Willingness to Pay for Residences	The willingness to pay for residences in circumstances of aircraft noise caused by airport expansion was examined, using a contingent valuation approach. The results show that most current compensation programs are inadequate, as they do not fully compensate homeowners or renters for the loss associated with higher noise exposure.
6	Pennington G., Topham N., and Ward R.	Aircraft Noise and Residential Property Values Adjacent to Manchester International Airport	The properties in the area affected by the noise of Manchester International Airport are of lower market values than those located outside. However, the whole of this difference can be attributed to the neighbourhood and other characteristics of properties.
7	Cohen J. and Coughlin C.	Changing Noise Levels and Housing Prices Near the Atlanta Airport	The paper describes the effect of time passing on the relationship between proximity to the airport and house prices (hedonic model).
8	Jud D. and Winkler D.	The Announcement Effect of an Airport Expansion on Housing Prices	Results based on a hedonic model, suggests that information about the airport's extension was related to the change of the prices of real estate in its neighbourhood.

Source: Own study [21,22,25,29–32].

Nonetheless, it is worth noting that although the body of the empirical research was based on case studies in different countries around the world, most of the evidence comes from mature property markets found in OECD countries. The empirical research on the correlation between noise and property prices (Noise Depreciation Index, NDI) has been synthesized in several meta-analyses, including Shipper, Nijkamp, and Rietveld [33], Nelson [34], and Wadud [35]. A recent meta-analysis compared revealed and stated preference data on NDI [9]. In yet another study, the authors used the result from the meta-analysis to estimate the economic cost of noise generated by 181 major airports in the world [36].

In Poland, the problem was long overlooked, and only recently empirical studies on the impact of airport noise on property prices have become available. The empirical research focused on major airports in Poland, mainly on the Poznan-Ławica airport [1,37], the Warsaw-Okecie airport [38] or the Katowice-Pyrzowice airport [39].

Compared to the relatively large body empirical evidence on the impact of aircraft noise on real estate prices, relatively little has been done to investigate other consequences of airport operation. One of the issues that have not received enough theoretical and empirical attention is land use restrictions around airports. Land use restrictions can significantly affect the operation of the land and housing market. A recent simulation-based study in the US has revealed that intensive zoning can result in a reallocation of development [40]. One obvious contagion effect of the latter would be a significant price premium observed for properties not subject to restrictive protection. Few empirical studies investigated the effect at micro-level, one of them being Gao et al. [41] who found a positive impact of maximum allowable development density imposed on land parcels (floor area ratio) and the land prices in Tokyo. The topic was also addressed in Poland. Recently, links between land use planning and property prices have been investigated by Forys and Putek [42], Zygmunt and Gluszak [43], and Gluszak and Zygmunt [44]. According to some authors [4], the land used regulations can result in three different effects. The first one is called an own-lot effect, which reflects the cost of regulatory constraints on how land is used. The next one is an external effect, which reflects the value of limitations (cost or benefit) on the use of nearby land. This effect is strongly linked to the distance proximately of the restricted area. The last one is a supply effect, which measures the result of imposed constraints on the supply of developable land. In the case of limitations related to the airport noise, we are focused on the own-lot effect and the supply effect.

To our best knowledge, there are few if any studies that have explicitly addressed the impact of land use restrictions related to the operation of an airport on property values. Restrictions can influence potential land use (for example banning residential development), limit the density of development, and impose additional regulations about technical conditions that must be met by new development (for example better sound isolation). As with airport noise, there is a reason to believe that land use restrictions are discounted in property values.

One of the major challenges is the fact that land use restrictions overlap aircraft noise patterns. Potential endogeneity related to the latter problem can lead to substantial bias in hedonic estimates of airport noise. The empirical problem is that noise and restrictions effects are sometimes hard to disentangle. In many cases, Limited Land Use Areas (or Restricted Land Use Areas) are explicitly based on noise maps. Joint effect of noise and land use restrictions is the subject of empirical investigation in this paper. In the next section, we describe the study areas and the empirical strategy applied.

3. Materials and Methods

3.1. Study Areas

In the paper, we investigate the influence of an airport on residential property prices. We try to assess the joint effect of (i) airport noise and (ii) land use restrictions (introduced via zoning plans and LLUAs). In this research, we analyse data on two out of twelve regional airports in Poland: the Katowice-Pyrzowice airport, and the Poznan-Lawica airport (Table 3).

Table 3. Comparison of basic characteristics of regional airports in Poland.

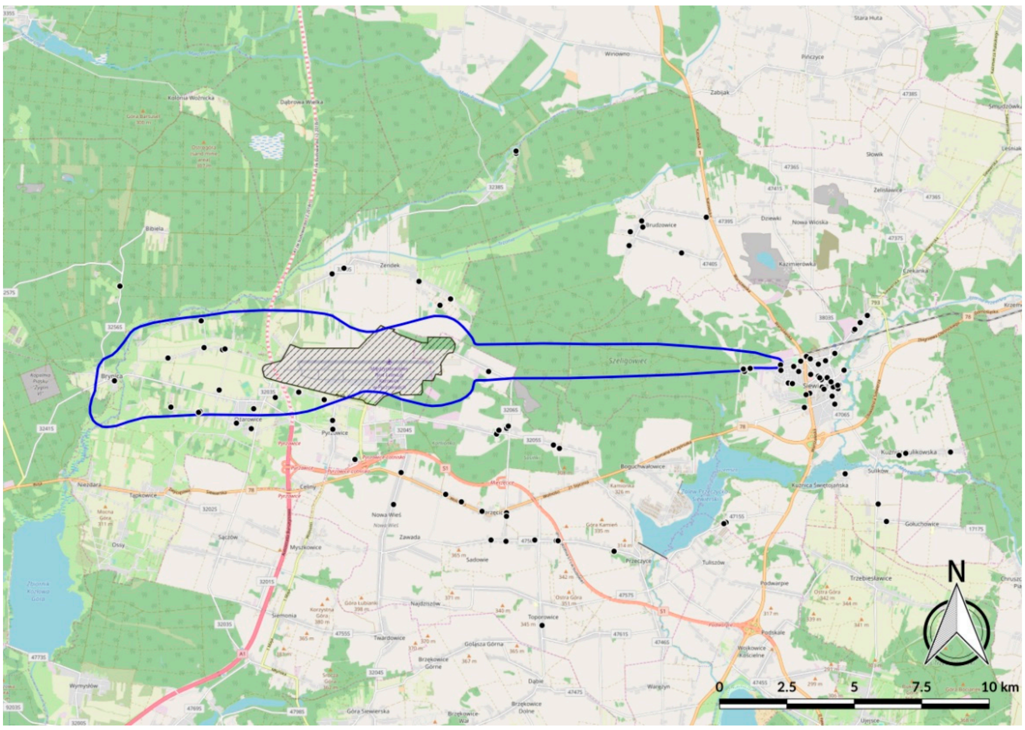
Indicator	Distance to the City Center (km)	Area (ha)	Length/Width of the Runway(s) (m)	Passengers in 2016 (1000s)	Regular Connections	LLUA
Bydgoszcz–Szwederowo	3	146	2500/ 60	322	7	NO
Gdańsk-Rebiechowo	10	240	2800/45	3986	60	YES
Katowice-Pyrzowice *	30	500	3200/45	3202	47	YES
Krakow-Balice	11	310	2550/60	4975	73	YES
Lodz-Lublinek	6	228	2500/60	241	5	NO
Poznan-Lawica *	7	310	2504/50	1689	30	YES
Szczecin-Goleniow	33	460	2500/ 60	467	10	NO
Rzeszow Jasionka	10	459	3200/45	662	14	NO
Warsaw-Modlin	35	293	2500/60	2859	54	YES
Warsaw-Okecie	8.5	500	3690/60; 2800/50	12,795	166	YES
Wrocław	10	472	2503/45	2371	55	YES
Zielona Gora	34	450	2500/60	9	1	NO

* Airports studied in this paper. Source: own study.

Both Katowice-Pyrzowice airport and the Poznan-Lawica airport are located in the western part of Poland. The basic selection criterion is based on their relative importance, that can be measured by the number of passengers served in recent years (based on which they are ranked as the 4th and the 7th airport in Poland respectively). While we can argue that both selected airports are relatively similar concerning the importance and geographic location, they differ significantly concerning an urban setting. Poznan-Lawica is located in the city of Poznan in a densely populated and heavily urbanised area. On the other hand, Katowice-Pyrzowice is located outside the urban area of Katowice in the less developed rural setting. This particular difference affects the activity on the housing market, measured by the number of sales in the study period. Another important difference is the date of the introduction of the LLUA. The LLUA around Poznan-Lawica was set up on 28 February 2012, whereas in the case of Katowice-Pyrzowice the LLUA was introduced on 15 September 2014. Due to the disparity in the dates of LLUA introduction the study uses different study periods for two selected airports: 2008–2014 for Poznan-Lawica and 2007–2016 for Katowice-Pyrzowice (longer study period needed to obtain a sufficient number of transactions). These study periods include the periods before and after LLUA introduction. A total number of 884 transactions were collected for Poznan Lawica (478 before and 406 after the introduction of LLUA). In the case of Katowice-Pyrzowice, the research was based on 109 transactions (87 before and 22 after the introduction of LLUA).

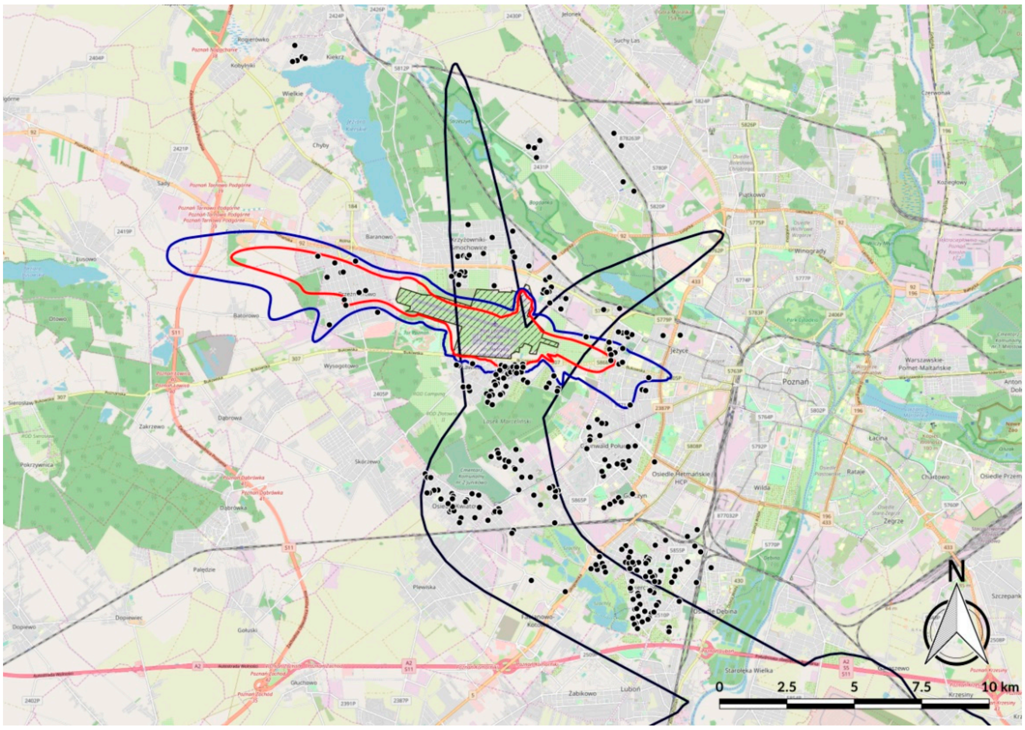
In both cases, the research is based on the data on house transactions (e.g., time of sale, sale price, information about buyer and seller) around the two selected airports and was obtained from notarial deeds gathered in the Real Estate Cadastre and the National Geodetic and Cartographic Resources. Additional information on house attributes (e.g., usable building area, lot area, technical condition of the building) was obtained by onsite scrutiny and additional spatial information available online. Transactions were geo-coded.

The comparison between the two airports can be interesting for two reasons. Firstly, the LLUAs in both cities have different introduction date and the extent of restrictions imposed. In the case of Katowice-Pyrzowice, inside the LLUA any conversion, extension, and refurbishment of residential buildings are restricted with regards to allowable building acoustic performance. As a result, sound absorption and noise reduction norms must be met in case of windows, as well as construction and materials for walls and ceilings. In the Poznan-Lawica case, the situation is more complex as two zones within the LLUA were created. In the inner LLUA zone restrictions regarding residential buildings are similar to those affecting properties around Katowice-Pyrzowice. No significant restrictions regarding residential buildings were imposed for properties located within the outer LLUA zone around Poznan-Lawica (Figure 1).



(a)

Figure 1. *Cont.*



(**b**)

Figure 1. Katowice-Pyrzowice and Poznan-Lawica airports with their respective LLUAs and property transactions in the study areas. Note: (**a**) Katowice-Pyrzowice airport with a blue border of LLUA; (**b**) Poznan-Lawica airport with blue and red borders of outer and inner LLUA zones. The black border is for overlapping LLUA border of military Krzesiny airport. In both cases, black dots are geo-coded property transactions that occurred during the study period.

Secondly, the activity reported on the market differs significantly due to location factors. As noted before, Katowice-Pyrzowice airport is located outside the major metropolitan area, and the residential property market around can be classified as inactive (thin). Out of 109 transactions during the study period, 89 were outside LLUA, and 20 inside LLUA. On the other hand, Poznan-Lawica airport is located more centrally within the city. The property market in the proximity is fairly active. Out of 884 recorded transactions, 824 were outside LLUA and 60 inside LLUA (18 in inner LLUA zone and 42 in outer LLUA zone). That resulted in a significant difference in sample size reported in each city (Figure 1).

3.2. Econometric Approach

We use hedonic regression to assess the joint effect of airport noise and the introduction of an LLUA on sales prices. To investigate the impact of the introduction of an LLUA around the airport on property prices we modified standard hedonic approach and used: (1) hedonic regression with linear splines as a baseline model, and (2) the difference-in-differences hedonic regression approach. Many sources confirm that the results obtained using hedonics models strongly depend on the functional form used [45], consideration of the temporal effect [46] and segmentation of the market [47]. In line with mainstream urban and housing research using hedonic models, the semi-log form was utilized. Although there are several advantages of more flexible and complex functional forms (like Box-Cox transformation), in the presence of omitted variables semi-log form is more robust and accurate [48].

To take account of the spatial dependence found in the house sales data, aside from the standard hedonic regression model (OLS), we used spatial regression models that take account of spatial disturbances, assuming that such approach outperforms standard specifications of the hedonic price functions [49]. Although there are at least two crucial questions related to the usefulness of such models: what kind of the model do we prefer and which estimation procedure is appropriate [32]. Fixity in location makes real estate subject to the various spatial phenomenon. Firstly, there are salient neighbourhood effects and environmental externalities that manifest locally and affect property prices. Some of them can be explicitly treated in a hedonic model, but some are not directly observed, sometimes due to data limitations [50]. The failure to account for unobserved factors induces omitted variable bias. The econometric model that explicitly addresses spatial heterogeneity, and can be used to correct for unobserved factors that affect property prices is spatial error model (SEM), and is given by [51,52]:

$$P = \beta X + \xi, \tag{1}$$

$$\xi = \lambda W \xi + \varepsilon.$$

where the dependent variable P is the property price, X is a vector of attributes affecting prices (structural, location, neighbourhood), and β is a vector of regression coefficients. In a second equation, W is a spatial weight matrix, λ is a spatial coefficient related to the autocorrelation of the error term, and ξ is an error term subject to spatial autocorrelation (a function of pure error term ε).

To account for a different kind of spatial dependence or spatial spillover effects, we used the Spatial Autoregressive Model (SAR), sometimes referred to as the Spatial Lag Model, both of them being particular cases of Spatial Durbin Model [53]. Spatial spillover is related to property prices being affected by the prices of properties in the neighbourhood (due to information flows, contagion effects). It requires a spatially lagged dependent variable to be included in the equation. Thus the hedonic model is given by [51]:

$$P = \rho W P + \beta X + \varepsilon \tag{2}$$

where ρ is the spatial lag coefficient for dependent variable and WP is the spatially-lagged dependent variable P.

The spatial weight matrix is a canonical concept of spatial econometrics used to define the spatial dependences between observations in the research sample. It represents an association between observations across space and is based on the intuition that distances between objects in an urban area are related to both similarity and propensity to influence one another [54]. There is no theory on the appropriate shape on this matrix, while different specifications lead to different results [13,55].

In our research, the spatial weight matrix was based on the geographic location of houses sold in the study period. The spatial weight matrix can be defined in many ways, most of them theoretically discussed and experimentally tested in the literature [56]. In our study, we used the inverse distance matrix W, commonly used in applied hedonic research. The choice of this particular distance is justified by the notion that property sales in proximity were significantly more related than ones further away.

Spline regression is a modification of standard regression that can be used to address structural change in the relationship between independent and dependent variables. It is a specific case of piecewise regression that does not allow for discontinuity. The methods were used within the hedonic regression framework by Smersh and Smith [57] and Chernobai, Reibel, and Carney [14]. We use a baseline spline regression model to check whether the house price dynamics changed significantly after the LLUA was introduced. Additionally, we investigate whether house price dynamics was similar within the area affected by airport noise (LLUA) and reference area outside. The spline regression approach appears to be more justified than piecewise regression since changes in house price dynamics should be gradual within the study period. The knots used in constructing splines are based on a date (month) of the introduction of the LLUAs in the Poznan-Lawica and Katowice-Pyrzowice airports relative to the beginning of the study period (January 2008 in case of Poznan and January 2007 in case of Katowice). For Katowice-Pyrzowice airport we applied the following hedonic model with linear splines:

$$\ln P = \alpha + \sum_{i=1}^{k} \beta_i X_i + \gamma TG + \tau month + \theta TGmonth + \varphi spline + \omega TGspline + \varepsilon \quad (3)$$

In a regression equation, ln$P$ is a dependent variable (natural logarithm of sale price), and X_i is the vector of control variables (salient real estate attributes that affect its price). *TG* (Treatment Group) is a dummy variable equal to 1 if a property is located within an LLUA and 0 otherwise. The *month* is a time variable related to the month the particular transaction took place (number of months since the beginning of the study). *Spline* is a time variable equal to 0 if the month is less than 93, and equal to *month* – 92 otherwise. Coefficient β captures the impact of selected property characteristics on property prices, while τ indicate the house price dynamics. Coefficient γ captures the price difference between the Treatment and Control groups at the beginning of the study period. The coefficients φ and ω of spline adjustment variables indicate the change in house price dynamics both in Control and Treatment group respectively, after LLUA introduction in September 2014.

The situation in Poznan was more complicated because two zones within the LLUA were formed. The inner zone was created based on the noise level equal to L_{AeqD} = 60 and L_{AeqN} = 50 dB, while the outer zone was based on the L_{AeqD} = 55 and L_{AeqN} = 45 dB noise levels. Due to multiple zones within the LLUA in Poznan, we modified our approach to reflect the possibility that house prices were not uniformly affected by different restrictions imposed in particular zones. To account for that we regressed natural logarithm sales price (P) on property characteristics X using the modified hedonic equation, with linear splines:

$$\begin{gathered} \ln P = \alpha + \textstyle\sum_{i=1}^{k} \beta_i X_i + \gamma_1 TG_{inner} + \gamma_2 TG_{outer} + \tau month + \\ \theta_1 monthTG_{inner} + \theta_2 monthTG_{outer} + \varphi spline + \omega_1 TG_{inner} spline + \omega_2 TG_{outer} spline + \varepsilon \end{gathered} \quad (4)$$

Compared to the previous case, TG_{inner} and TG_{outer} are the Treatment Group dummy variables equal to 1 if a property is located within particular LLUA zones (inner and outer). *Spline* is a time variable equal to 0 if *month* is less than 50, and equal to *month* – 49 otherwise. Coefficients γ_1, γ_2 indicate the difference between sale price of properties located in particular area in relation to control area outside the influence of the airport. Coefficients θ_1 and θ_2 capture the difference in price dynamics in both zones prior to the formal introduction of LLUA in February 2012 relative to the control area, and coefficients ω_1 and ω_2 capture the impact of the introduction of an LLUA on property price dynamics, separately for the inner and the outer LLUA zone.

As a robustness check, we applied the difference-in-differences approach. As noted before, LLUAs are not assigned randomly, which may result in the endogeneity problem when building a hedonic price model. As noted by Gibbons and Machin [58] the traditional hedonic approach based on cross-sectional data does not account for the potential endogeneity problem, in our case mostly caused by unobserved noise level differences and other airport operation related risk. To address the problem of endogeneity, and to assess the causal effect of the introduction of an LLUA on house prices we use the difference-in-differences (DiD) approach. The method is based on a comparison of a before-after estimate of house prices in an LLUA (Treated Group, TG) to a comparable properties sales prices outside of this area (Control Group, CG).

Following the general guidelines of the difference-in-differences method based on individual data, for Katowice-Pyrzowice airport we applied the model:

$$\ln P = \alpha + \sum_{i=1}^{k} \beta_i X_i + \gamma TG + \tau post + \theta TGpost + \varepsilon \quad (5)$$

In the regression equation X_i is the vector of control variables (salient real estate attributes), TG (Treatment Group) is a dummy variable equal to 1 if a property is located within an LLUA and 0 otherwise. *Post* is a dummy variable equal to 1 when the sale occurred after the introduction of an LLUA. Coefficient β captures the impact of selected property characteristics on property prices. Coefficient γ captures price difference between the Treatment and Control groups before the introduction of LLUAs around the airport. The latter can be interpreted as a difference caused by the externalities generated by the airport's operation, mainly aircraft noise because the LLUA was defined based on future aircraft noise level (L_{AeqN} = 50 dB in 2020, which closely corresponds to current noise levels during night). Coefficient τ depicts market related price changes in a control group. The role of θ is to capture the pure impact of the introduction of an LLUA on property prices.

As noted before, the situation in Poznan was more complicated, thus in the case of the Poznan-Lawica airport we regressed natural logarithm of the sale price (P) on property characteristics using the modified DiD estimator:

$$\ln P = \alpha + \sum_{i=1}^{k} \beta_i X_i + \gamma_1 TG_{inner} + \gamma_2 TG_{outer} + \tau post + \theta_1 TG_{inner} post + \theta_2 TG_{outer} post + \varepsilon \quad (6)$$

In this modified approach TG_{inner} and TG_{outer} are Treatment Group dummy variables equal to 1 if a property is located within particular LLUA zones (inner and outer). Other abbreviations as in previous equation. Coefficients γ_1 and γ_2 capture the noise effect, and coefficients θ_1 and θ_2 capture the impact of the introduction of an LLUA on property prices, separately for the inner and the outer LLUA zone.

In this paper we estimated three types of hedonic models (OLS, SAR, and SEM) using both the spline and DiD approach. After repeating the procedure for the two airports we finally obtained 12 models (three specifications, two approaches, and two airports). As discussed previously, as a robustness check the estimates obtained from DiD regression were compared to the baseline spline regression approach. We also compared the differences in the results between both airports.

4. Results

4.1. Katowice-Pyrzowice Airport Case Study

In the study, we applied a hedonic regression framework using linear splines in order to obtain an unbiased estimate of the implicit discount related to the introduction of land use restrictions. We also controlled for other relevant house features. Due to data availability, in case of the Katowice-Pyrzowice airport, we were able to use four major attributes. We controlled for the usable building area, lot area, technical condition of the building assessed by an expert valuer on a six-point scale, from very poor/emergency (0) to excellent (5), and the construction advancement stage [59]. The list of variables is presented in Table 4.

Table 4. Control variables for the Katowice-Pyrzowice airport.

Variables	Description	Mean	SD	Min	Max
lnbldarea	Usable building area in meters (natural logarithm)	4.75	0.59	3.18	6.94
lnlotarea	Lot area in meters (natural logarithm)	7.44	1.10	5.78	10.13
techcond	Technical condition of the building	2.75	1.29	0	5
stage	Construction advancement stage	frame (3.75%); lockup (5.5%); fit out (3.67%); completed * (88.07%)			

* base category in hedonic regression models.

Having controlled for the most relevant property characteristics, we investigated the impact of the introduction of an LLUA on property prices. Based on the hedonic framework with linear splines (Eq. 3) we estimated three hedonic price models—classic OLS and two spatial hedonic SAR models (Spatial Autoregressive model, Spatial Lag Model) and SEM (Spatial Error Model). The latter two models could potentially mitigate the problem of unobserved neighbourhood effect or spatial spillovers. In both cases, we used the inverse distance spatial weight matrix. Estimation was made in STATA 13.1 with the *spatreg* module (by M. Pisati). The results are presented in Table 5. The dependent variable was natural logarithm of the sales price.

Table 5. Spline regression models for the Katowice-Pyrzowice airport.

Variables	OLS_spline	SAR_spline	SEM_spline
lnbldarea	0.780 ***	0.781 ***	0.780 ***
lnlotarea	0.099 *	0.099 *	0.098 *
techcond	0.194 ***	0.196 ***	0.198 ***
stage (frame)	−0.712 **	−0.715 ***	−0.708 ***
stage (lockup)	−0.300	−0.303	−0.290
stage (fit out)	−0.279	−0.289	−0.309
month	0.003	0.003	0.003
TG	0.025	0.015	0.011
TG*month	0.000	0.000	0.000
spline	−0.005	−0.005	−0.004
TG*spline	−0.025	−0.025	−0.027
Constant	7.097 ***	6.659 ***	7.103 ***
ϱ		0.036	
λ			0.133
R-squared	0.615		
N	109	109	109

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

The models have an average fit to empirical data (R-squared in the OLS model is equal to 0.615), but due to the sample size only selected variables significantly affect house prices. The results did not differ significantly between the OLS, SAR and SEM models. It is worth noting that spatial coefficients (λ, ϱ) were not statistically significant. The latter result, backed by Moran I and LM tests of spatial dependence lack of significant spatial dependences in the sample. This may indicate that neighbourhood effects, and unobserved location externalities did not significantly alter the results. Sales prices were strongly influenced by both usable building area (elasticity = 0.78) and lot area (0.1). The price depended on the technical condition of the building (*techcond*), as well as completion stage (although in case of the latter we were able to get statistically significant effect only for the frame completion stage). As expected, finished buildings in better technical conditions were sold for a higher price, all other things being equal.

We have not observed a statistically significant difference between sales prices inside and outside the LLUA before it was announced (insignificant coefficient of the *TG* variable). This may indicate that noise differences have not affected house prices significantly, because the LLUA was defined based on noise level.

The data has not revealed any significant price dynamics during the study period, both before and after September 2014 (*month* and *spline* coefficient close to 0, and statistically insignificant). The same observation applies to differences in house price dynamics between the LLUA and the reference housing market area. We were especially interested in finding whether the house price trend has changed for properties affected by the introduction of the LLUA after September 2014. Although the *TG*spline* coefficient is negative, which is a plausible and expected result of the introduction of land use restrictions in the area around the airport, the result is not statistically significant (at alpha = 0.05). Nonetheless, a word of caution is needed here. The lack of statistical significance can have a more practical explanation. It can be a result of the relatively small transaction sample (out of 20 sales recorded in the study area after the introduction of LLUA, only 4 were inside the LLUA itself).

As a robustness check, we estimated the DiD model (Equation (5)) using the OLS, SAR and SEM specifications. The dependent variable was a natural logarithm of the sales price. The results are presented in Table 6.

Table 6. Difference-in-differences models for the Katowice-Pyrzowice airport.

Variables	DiD_OLS	DiD_SAR	DiD_SEM
lnbldarea	0.751 ***	0.752 ***	0.750 ***
lnlotarea	0.108 *	0.108 **	0.107 *
techcond	0.197 ***	0.199 ***	0.204 ***
stage (frame)	−0.718 ***	−0.721 ***	−0.713 ***
stage (lockup)	−0.241	−0.244	−0.232
stage (fit out)	−0.289	−0.296	−0.323
TG	0.133	0.124	0.118
post	0.150	0.147	0.146
TG*post	−0.707 *	−0.703 *	−0.736 *
Constant	7.290 ***	6.929 ***	7.295 ***
ϱ		0.029	
λ			0.149
R-squared	0.624		
N	109	109	109

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Coefficients for control variables in the DiD models are similar to those from the spline regression models. Spatial models results were similar to OLS estimates (spatial coefficients once again insignificant). Sales prices were strongly influenced by both usable building area (elasticity = 0.75) and lot area (0.1). Technical condition and completion stage also affect the property prices, similarly to the baseline spline regression model. We have observed the difference between the treatment group (properties located within the LLUA) and the control group (properties located outside the LLUA) in the period before the introduction of the LLUA. A positive sign of the coefficient suggests that despite being affected by higher aircraft noise, the price paid for residential properties was higher. Nonetheless, no conclusions can be drawn because the coefficient was not statistically significant. The latter is mainly due to the relatively thin housing market around Katowice-Pyrzowice.

Contrary to spline regression, the difference-in-differences model suggests a statistically significant drop in the values of houses sold inside the LLUA after it was introduced. Based on the value of the *TG*post* coefficient (−0.707), we can conclude that prices decreased by as much as 51%. The same was not observed outside the LLUA. Although the direction of the effect is plausible, the size of the effect is not equally justified. We believe the result must be treated with caution due to the relatively low activity of the market since September 2014 when the LLUA was introduced (only 20 transactions, out of which four were inside the LLUA). Even though spatial regression models take account of unobserved neighbourhood effects, the significant share of this sudden drop can be attributed to other unobserved characteristics (as we were only able to monitor only some of the key structural variables).

There is an alternative explanation, in line with the recent urban economics research that examines the impact of asymmetric information on the hedonic equilibrium. The hedonic model assumes the house buyer having access to available information, thus amenities (disamenities) are effectively capitalized (discounted) in property prices. Several empirical studies have suggested among many markets that asymmetric information can lead to market distortions. If it is the case, airport noise may not effectively influence the choices of house buyers (and in the NDI). Introduction of the LLUA, apart from the restriction on property use, is, in fact, public disclosure of noise levels. It increases aircraft noise awareness of the local community and house buyers. Moreover, in case of Katowice-Pyrzowice the LLUA was defined based on the forecast of the airport noise level in 2022, thus house price adjustment process can be related to the anticipatory effect (found in several studies related to infrastructure provision and its impact on the property market). Nonetheless, we believe that for the relatively thin and inactive housing market around the Katowice-Pyrzowice airport land use restrictions provide a more plausible explanation.

4.2. Poznan-Lawica Airport Case Study

In the study, we applied the hedonic regression framework. In order to obtain an unbiased estimate of the implicit discount related to the introduction of land use restrictions, we had to control for other relevant house features. Due to data availability, in case of the Poznan-Lawica airport, we were able to use more attributes. We controlled for the building area, lot area, technical condition of the building, assessed by an expert valuer on a three-point scale from 1 (poor) to 3 (very good), and the distance from the city centre (as the airport was located inside the municipal area of Poznan). Additionally, we controlled for the influence of Krzesiny Military Airport land use restrictions (in many cases the latter overlapped with the Poznan-Lawica Airport LLUAs). The latter was crucial in order to disentangle the pure effect of the introduction of the Poznan-Lawica Airport LLUA on sales prices. The list of control variables is presented in Table 7.

Table 7. Control variables for the Poznan-Lawica airport.

Variables	Description	Mean	SD	Min	Max
lnbldarea	Building usable area in meters (natural logarithm)	4.97	0.39	2.94	6.55
lnlotarea	Lot area in meters (natural logarithm)	6.08	0.57	4.77	8.92
distance	Distance from the city centre in km	7.79	2.37	1.79	16.00
Krzesiny	1 if located inside the Krzesiny Military Airport LLUA; 0 otherwise	0.43	0.49	0	1
techcond	Technical condition of the building	2.22	0.67	1	3

As previously, we estimated three hedonic price models with linear splines (Equation (4))—classic OLS and two spatial SAR hedonic models (Spatial Autoregressive model, Spatial Lag Model) and SEM (Spatial Error Model). Results are presented in Table 8. The dependent variable was a natural logarithm of the sales price.

Table 8. Spline regression models for the Poznan-Lawica airport.

Variables	spline_OLS	spline_SEM	spline_SAR
lnbldarea	0.633 ***	0.633 ***	0.633 ***
lnlotarea	0.121 ***	0.121 ***	0.121 ***
distance	−0.023 ***	−0.023 ***	−0.023 ***
Krzesiny	−0.007	−0.007	−0.007
techcond	0.219 ***	0.219 ***	0.220 ***
TG1 (inner)	−0.009	−0.007	−0.014
TG2 (outer)	−0.148	−0.148	−0.146
month	-0.000	−0.000	0.000
spline	−0.003 ***	−0.003 ***	−0.003 ***
TG1 (inner)*month	0.003	0.003	0.004
TG2 (outer)*month	0.007 *	0.007 *	0.007 *
TG1 (inner)*spline	−0.014	−0.015	−0.015
TG2 (outer)*spline	−0.012 *	−0.012 *	−0.012 *
Constant	9.114 ***	9.114 ***	8.155 ***
ϱ			0.072
λ		−0.016	
R-squared	0.689		
N	884	884	884

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

The models for the Poznan-Lawica airport have a slightly better fit to empirical data than in the case of the Katowice-Pyrzowice airport (R-squared in the OLS model is equal to 0.689). Similarly, we have not observed significant spatial dependence. Control variables coefficients have expected and intuitive signs. The results suggest that both building area and lot area significantly increase sales price (elasticity 0.633 and 0.121, respectively). The same applies to the technical condition of the building. The sale prices decreased along with the distance to the city centre (in line with urban economics theories). We have not found a significant trend in price dynamics during the study period. The prices decreased a bit in 2014. The results suggest that a decrease was reported for both the inner and outer LLUAs, but only in case of the latter, the coefficient was statistically significant. We conclude that more detailed data is needed to get conclusive results (we were not able to control for some of the neighbourhood characteristics due to the data availability problem).

As a robustness check, yet again we estimated a DiD model (Equation (6)). Results are presented in Table 9. As previously, the dependent variable was a natural logarithm of the sales price.

Table 9. Difference-in-Differences models for Poznan-Lawica airport.

Variables	DiD_OLS	DiD_SEM	DiD_SAR
lnbldarea	0.623 ***	0.623 ***	0.623 ***
lnlotarea	0.122 ***	0.122 ***	0.122 ***
distance	−0.023 ***	−0.023 ***	−0.024 ***
KS	−0.008	−0.008	−0.008
techcond	0.221 ***	0.221 ***	0.222 ***
TG1 (inner)	0.038	0.030	0.035
TG2 (outer)	0.091	0.094	0.093
post	−0.059 ***	−0.057 ***	−0.053 **
TG1 (inner)*post	−0.176	−0.165	−0.173
TG2 (outer)*post	−0.033	−0.037	−0.035
Constant	9.156 ***	9.156 ***	8.012 ***
ϱ			0.086
λ		0.114	
R-squared	0.686		
N	884	884	884

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

The results are in line with spline regression in most cases. Both building and lot area explained property prices. Transaction prices were also affected by the technical condition of houses being sold. In line with the urban economic theory, the distance from the city centre significantly reduced the sale prices in Poznan (1 km increase in distance reduced prices by 2.3%). The location of a military airport within LLUA Krzesiny was of no significant effect.

We have not found a significant decrease in sale prices in both the inner and outer LLUAs after they were introduced. Although similar to the previous findings, we observed negative coefficients for the DiD variables (−0.176 for inner LLUA zone and –0.033 for outer LLUA zone), the coefficients were not statistically significant.

5. Discussion

The results of empirical investigation generally suggest that the introduction of LLUA had a negative effect on prices of the property affected (Treatment Group) compared to similar properties located outside LLUA (Control Group). Nonetheless, we got statistically significant estimates only for some of the models estimated (DiD specification for Katowice-Pyrzowice and linear spline specification for Poznan-Lawica). Although the signs of the coefficients were intuitive (in line with prior expectations), the effect size differed across specifications. In some cases, the results did not seem plausible (for example DiD specification for Katowice-Pyrzowice).

Although inconclusive, the estimates suggest that the effect of the introduction of an LLUA on property prices to some extent depends on the restrictions imposed on property owners (Katowice-Pyrzowice or inner Poznan-Lawica LLUA). In general, as expected, more rigid restrictions seem to translate into higher discount in property prices, but again not always the results were statistically significant. Moreover, further research will have to deal with data quality issue—both omitted variable bias and measurement problem [59,60]. We conclude that more research is needed, especially because the problems of land use restrictions related to the operation of airports and its impact on property prices have been generally overlooked in the empirical research. To our best knowledge, it is the first study that searches for the linkages while controlling for aircraft noise impact.

The research findings on airport externalities have several practical implications, as demonstrated in many recent papers [25]. Like many other papers on the nexus between environmental sustainability and economic development [61], our research related to the restrictions resulting from the introduction of limited use areas (LUAs) around two large Polish airports is a pioneering one, as it does not concern only acoustic damage. They are part of a wider problem related to the risk of airport management. This risk is due to the not fully quantified scope of compensation and the unclear jurisprudence on the sequencing of payments, including the duplication of acoustic and proprietary damages after the introduction of the LUA. Therefore, further studies can be continued in two directions: assessment of the scale of discrepancies between the expectations of property owners as to the amount of loss and the estimated values, taking into account econometric models (including non-linear ones). On the other hand, airport risks related to further investment plans and potential claims will be estimated, taking into account the location options of new investments. The problem of inactive markets, where transactions in similar real estate are not quoted, also remained unresolved methodically. The solution lies in the extent to which parallel markets in the vicinity of other airports can be addressed in such situations. The meta-analysis could be used to identify variables that could be indicative of the similarity of these market situations, and the impact of land use regulations related to the operation of different airports on property prices. The latter research would supplement the findings of recent systematic surveys on the monetary value of aircraft noise.

6. Conclusions

In the study, we examined the joint effect of both airport noise and land use restriction on property prices around selected regional airports in Poland. We estimated several hedonic models (with linear spline regression models and using difference-in-differences approach) for two airports—Katowice-Pyrzowice and Poznan-Lawica. Despite using data for all house sales around two regional airports observed over a relatively long period (before and after the introduction of respective LLUAs) the findings are mixed and partially inconclusive. We were not able to find significant effects in all the models used (latter empirical strategy was applied to check the robustness of the findings). Although a direct comparison of the effects between selected regional airports was not an explicit objective of the study, we have found some similarities. The research differs from many prior studies because we focused on the land use restrictions due to negative externalities generated by the airport operations (mainly aircraft noise) not the relation between property prices and noise itself. Contrary to some other recent research [62], we have not found strong evidence to support the hypothesis that the introduction of LLUA has a significant impact on property prices. We found some evidence that the introduction of land use restrictions can cause property price decrease, yet the results remain fairly inconclusive (and dependent on model specification). We contribute this effect to fairly inactive single-family housing markets in the proximity of the investigated airports—a situation that is quite typical to many regional airports in Poland.

Author Contributions: The authors were altogether involved in project design, and its conceptualization. J.B. and I.F. were involved in methodology literature review; M.G. contributed to data analysis; R.G. contributed to collecting and processing of the empirical data and visualization; J.K. was responsible for supervision and project administration. All authors contributed to writing of the paper and approved its final version.

Funding: Authors acknowledge financial support from University of Economics in Katowice, Center for Research and Transfer of Knowledge (grant number RPO-RU 339/2016).

Acknowledgments: The paper was presented at American Real Estate and Urban Economics Association International Conference held in Amsterdam in 2017. Authors would like to thank participants for their insightful comments, suggestion and questions.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Trojanek, R.; Tanas, J.; Raslanas, S.; Banaitis, A. The Impact of Aircraft Noise on Housing Prices in Poznan. *Sustainability* **2017**, *9*, 2088. [CrossRef]
2. Brueckner, J.K. Airline traffic and urban economic development. *Urban Stud.* **2003**, *40*, 1455–1469. [CrossRef]
3. Kopsch, F. The cost of aircraft noise – Does it differ from road noise? A meta-analysis. *J. Air Transp. Manag.* **2016**, *57*, 138–142. [CrossRef]
4. Turner, M.A.; Haughwout, A.; van der Klaauw, W. Land Use Regulation and Welfare. *Econometrica* **2014**, *82*, 1341–1403.
5. Environmental Protection Act 2001 (No. 2001. 62.627). Available online: http://prawo.sejm.gov.pl/isap.nsf/download.xsp/WDU20010620627/T/D20010627L.pdf (accessed on 12 November 2018).
6. Freeman, M.A.; Herriges, J.A.; Kling, C.L. *The Measurement of Environmental Resource Values*; Routledge: New York, NY, USA, 2014; ISBN 978-1-315-78091-7.
7. Nelson, J. Hedonic Property Value Studies of Transportation Noise: Aircraft and Road Traffic. In *Hedonic Methods in Housing Markets: Pricing Environmental Amenities and Segregation*; Baranzini, A., Ramirez, J., Schaerer, C., Thalmann, P., Eds.; Springer: New York, NY, USA, 2008; pp. 57–82, ISBN 978-0-387-76815-1.
8. Trojanek, R.; Gluszak, M. Spatial and time effect of subway on property prices. *J. Hous. Built Environ.* **2018**, *33*, 359–384. [CrossRef]
9. Bristow, A.L.; Wardman, M.; Chintakayala, V.P.K. International meta-analysis of stated preference studies of transportation noise nuisance. *Transp. (Amst)* **2014**, *42*, 71–100. [CrossRef]
10. Salvi, M. Spatial Estimation of the Impact of Airport Noise on Residential Housing Prices. *Swiss J. Econ. Stat.* **2008**, *144*, 577–606. [CrossRef]
11. Sunding, D.L.; Swoboda, A.M. Hedonic analysis with locally weighted regression: An application to the shadow cost of housing regulation in Southern California. *Reg. Sci. Urban Econ.* **2010**, *40*, 550–573. [CrossRef]
12. Winke, T. The impact of aircraft noise on apartment prices: A differences-in-differences hedonic approach for Frankfurt, Germany. *J. Econ. Geogr.* **2017**, *17*, 1283–1300. [CrossRef]
13. Kuminoff, N.V.; Parmeter, C.F.; Pope, J.C. Which hedonic models can we trust to recover the marginal willingness to pay for environmental amenities? *J. Environ. Econ. Manag.* **2010**, *60*, 145–160. [CrossRef]
14. Chernobai, E.; Reibel, M.; Carney, M. Nonlinear Spatial and Temporal Effects of Highway Construction on House Prices. *J. Real Estate Financ. Econ.* **2009**, *42*, 348–370. [CrossRef]
15. Theebe, M.A.J. Planes, Trains, and Automobiles: The Impact of Traffic Noise on House Prices. *J. Real Estate Financ. Econ.* **2004**, *28*, 209–234. [CrossRef]
16. Bateman, I.; Day, B.; Lake, I. The Effect of Road Traffic on Residential Property Values: A Literature Review and Hedonic Pricing Study. In *Bateman, Ian Day, Brett Lake, Iain Lovett, Andrew*; 2001; p. 208. Available online: https://www2.gov.scot/Resource/Doc/158818/0043124.pdf (accessed on 9 January 2019).
17. Wilhelmsson, M. The Impact of Traffic Noise on the Values of Single-family Houses. *J. Environ. Plan. Manag.* **2000**, *43*, 799–815. [CrossRef]
18. Diao, M.; Qin, Y.; Sing, T.F. Negative Externalities of Rail Noise and Housing Values: Evidence from the Cessation of Railway Operations in Singapore. *Real Estate Econ.* **2015**, *44*, 878–917. [CrossRef]
19. Dekkers, J.E.C.; van der Straaten, J.W. Monetary valuation of aircraft noise: A hedonic analysis around Amsterdam airport. *Ecol. Econ.* **2009**, *68*, 2850–2858. [CrossRef]
20. Püschel, R.; Evangelinos, C. Evaluating noise annoyance cost recovery at Düsseldorf International Airport. *Transp. Res. Part D Transp. Environ.* **2012**, *17*, 598–604. [CrossRef]
21. McMillen, D.P. Airport expansions and property values: The case of Chicago O'Hare airport. *J. Urban Econ.* **2004**, *55*, 627–640. [CrossRef]
22. Jud, G.D.; Winkler, D.T. The Announcement Effect of an Airport Expansion on Housing Prices. *J. Real Estate Financ. Econ.* **2006**, *33*, 91–103. [CrossRef]
23. Thanos, S.; Bristow, A.L.; Wardman, M.R. Theoretically consistent temporal ordering specification in spatial hedonic pricing models applied to the valuation of aircraft noise. *J. Environ. Econ. Policy* **2012**, *1*, 103–126. [CrossRef]

24. Baranzini, A.; Ramirez, J.V. Paying for Quietness: The Impact of Noise on Geneva Rents. *Urban Stud.* **2005**, *42*, 633–646. [CrossRef]
25. Suksmith, P.; Nitivattananon, V. Aviation Impacts on Property Values and Management: The Case of Suvarnabhumi International Airport. *IATSS Res.* **2015**, *39*, 58–71. [CrossRef]
26. Beimer, W.; Maennig, W. Noise effects and real estate prices: A simultaneous analysis of different noise sources. *Transp. Res. Part D Transp. Environ.* **2017**, *54*, 282–286. [CrossRef]
27. Ahlfeldt, G.M.; Maennig, W. External Productivity and Utility Effects of City Airports. *Reg. Stud.* **2013**, *47*, 508–529. [CrossRef]
28. Andrzejewski, J.; Trojanek, M.; Pawłowska, M.; Kosmowski, M. Hałas lotniczy a wartość nieruchomości. *Biul. Stowarzyszenia Rzeczozn. Majątkowych Wojewodztwa Wielkop.* **2014**, *3*, 34–49.
29. Rahmatian, M.; Cockerill, L. Airport noise and residential housing valuation in southern California: A hedonic pricing approach. *Int. J. Environ. Sci. Technol.* **2004**, *1*, 17–25. [CrossRef]
30. Feitelson, E.I.; Hurd, R.E.; Mudge, R.R. The impact of airport noise on willingness to pay for residences. *Transp. Res. Part D Transp. Environ.* **1996**, *1*, 1–14. [CrossRef]
31. Pennington, G.; Topham, N.; Ward, R. Aircraft Noise and Residential Property Values Adjacent to Manchester International Airport. *J. Transp. Econ. Policy* **1990**, *24*, 49–59.
32. Cohen, J.P.; Coughlin, C.C. Changing Noise Levels and Housing Prices Near the Atlanta Airport. *Growth Chang.* **2009**, *40*, 287–313. [CrossRef]
33. Schipper, Y.; Nijkamp, P.; Rietveld, P. Why do aircraft noise value estimates differ? A meta-analysis. *J. Air Transp. Manag.* **1998**, *4*, 117–124. [CrossRef]
34. Nelson, J. Meta-Analysis of Airport Noise and Hedonic Property Values: Problems and Prospects. *J. Transp. Econ. Policy* **2004**, *38*, 1–28.
35. Wadud, Z. Using meta-regression to determine Noise Depreciation Indices for Asian airports. *Asian Geogr.* **2013**, *30*, 127–141. [CrossRef]
36. He, Q.; Wollersheim, C.; Locke, M.; Waitz, I. Estimation of the global impacts of aviation-related noise using an income-based approach. *Transp. Policy* **2014**, *34*, 85–101. [CrossRef]
37. Biłozor, A.; Reniger-Biłozor, A.; Furman, A. Multi-Criteria Land Use Function. *Real Estate Manag. Valuat.* **2015**, *23*, 81–91. [CrossRef]
38. Trojanek, R. The impact of aircraft noise on the value of dwellings – The case of Warsaw Chopin airport in Poland. *J. Int. Stud.* **2014**, *7*, 155–161. [CrossRef]
39. Habdas, M.; Gluszak, M.; Konowalczuk, J.; Ramian, T. Airport vicinity—A blessing or a curse? Paradoxes of calculating loss of value for residential properties. In Proceedings of the American Association of Geographers Conference, Boston, MA, USA, 5–9 April 2017.
40. Zipp, K.Y.; Lewis, D.J.; Provencher, B. Does the conservation of land reduce development? An econometric-based landscape simulation with land market feedbacks. *J. Environ. Econ. Manag.* **2017**, *81*, 19–37. [CrossRef]
41. Gao, X.; Asami, Y.; Katsumata, W. Evaluating land-use restrictions concerning the floor area ratio of lots. *Environ. Plan. C Gov. Policy* **2006**, *24*, 515–532. [CrossRef]
42. Foryś, I.; Putek, E. The Influence of Planning Decisions Regarding Land Evaluation Based on A Selected Local Real Estate Market. *Real Estate Manag. Valuat.* **2015**, *23*, 62–73. [CrossRef]
43. Zygmunt, R.; Gluszak, M. Forest proximity impact on undeveloped land values: A spatial hedonic study. *For. Policy Econ.* **2015**, *50*, 82–89. [CrossRef]
44. Gluszak, M.; Zygmunt, R. Development density, administrative decisions and land values: An empirical investigation. *Land Use Policy* **2017**, *70*, 153–161. [CrossRef]
45. Halvorsen, R.; Pollakowski, H.O. Choice of functional form for hedonic price equations. *J. Urban Econ.* **1981**, *10*, 37–49. [CrossRef]
46. Devaux, N.; Dubé, J. About the Influence of Time on Spatial Dependence: A Meta-analysis using Real Estate Hedonic Pricing Models. *J. Real Estate Lit.* **2016**, *24*, 31–66.
47. Bourassa, S.; Cantoni, E.; Hoesli, M. Predicting House Prices with Spatial Dependence: A Comparison of Alternative Methods. *J. Real Estate Res.* **2010**, *32*, 139–159.
48. Cropper, M.L.; Deck, L.B.; McConnell, K.E. On the Choice of Funtional Form for Hedonic Price Functions. *Rev. Econ. Stat.* **1988**, *70*, 668. [CrossRef]

49. Day, B.; Bateman, I.; Lake, I. Beyond implicit prices: Recovering theoretically consistent and transferable values for noise avoidance from a hedonic property price model. *Environ. Resour. Econ.* **2007**, *37*, 211–232. [CrossRef]
50. Small, K.A.; Steimetz, S.S.C. Spatial hedonics and the willigness to pay for residential amenities. *J. Reg. Sci.* **2012**, *52*, 635–647. [CrossRef]
51. Griffith, D.A.; Paelinck, J.H.P. *Non-Standard Spatial Statistics and Spatial Econometrics*; Springer: Berlin, Germany, 2012; ISBN 9783642135583.
52. Anselin, L.; Rey, S. The Performance of Tests for Spatial Dependence in a Linear Regression. *Geogr. Anal.* **1991**, *23*, 112–131. [CrossRef]
53. Montero, J.-M.; Fenandez-Aviles, G.; Minguez, R. Spatial Hedonic Pricing Models for Testing the Adequacy of Acoustic Areas in Madrid, Spain. *Investig. Reg.* **2011**, *21*, 157–182.
54. Anselin, L. GIS Research Infrastructure for Spatial Analysis of Real Estate Markets. *J. Hous. Res.* **1998**, *9*, 113–133.
55. Tsutsumi, M.; Seya, H. Hedonic approaches based on spatial econometrics and spatial statistics: Application to evaluation of project benefits. *J. Geogr. Syst.* **2009**, *11*, 357–380. [CrossRef]
56. Wilhelmsson, M. Spatial models in real estate economics. *Hous. Theory Soc.* **2002**, *19*, 92–101. [CrossRef]
57. Smersh, G.T.; Smith, M.T. Accessibility Changes and Urban House Price Appreciation: A Constrained Optimization Approach to Determining Distance Effects. *J. Hous. Econ.* **2000**, *9*, 187–196. [CrossRef]
58. Gibbons, S.; Machin, S. Valuing rail access using transport innovations. *J. Urban Econ.* **2005**, *57*, 148–169. [CrossRef]
59. Foryś, I.; Gaca, R. Theoretical and practical aspects of qualitative variable descriptions of residential property valuation multiple regression models. In Proceedings of the Proceedings of the 10th Professor Aleksander Zelias International Conference on Modelling and Forecasting of Socio-Economic Phenomena, Zakopane, Poland, 10–13 May 2016.
60. Gaca, R. Parametric and Non-Parametric Statistical Methods in the Assessment of the Effect of Property Attributes on Prices. *Real Estate Manag. Valuat.* **2018**, *26*, 83–91. [CrossRef]
61. Kazak, J.; Dziezyc, H.; Forys, I.; Szewranski, S. Indicator-based analysis of socially sensitive and territorially sustainable development in relation to household energy consumption. *Eng. Rural Dev.* **2018**, *17*, 1653–1661.
62. Trojanek, R.; Huderek-Glapska, S. Measuring the noise cost of aviation—The association between the Limited Use Area around Warsaw Chopin Airport and property values. *J. Air Transp. Manag.* **2018**, *67*, 103–114. [CrossRef]