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Regional Airports and Economic Growth: Evidence from the Single European Aviation Market

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Abstract: This paper exploits market changes induced by the Single European Aviation market liberalization initiative to bring new evidence on the link between regional airports and economic development. Using administrative level data for the EU-15, a difference-in-differences research design is applied to identify the causal effects and spillovers of regional airports on local economic activity, population, and employment. The results suggest that the presence of regional airports on economic activity in the EU is positive and ranges between 2 and 6 percent. Population levels increase between 1 and 3 percent and the effect on employment is in the magnitude of 2 percent. An additional instrumental variable estimation points towards a similar outcome, with each additional 1 million passengers yielding to a positive effect between 2 and 3 percent on GDP.

Keywords: airport impact, market liberalization, regional development, air transport

JEL Code: L93, R42, R51

1. Introduction

Inspired by the initial success of the 1978 U.S. Airline Deregulation Act, which transformed its aviation industry into a single domestic aviation market, the European Union sought to embark on a similar, yet perhaps more challenging journey. The fragmented and primarily international nature of the EU aviation industry required a more cautious approach to reform its air transport landscape. At the time, the European aviation market was governed by numerous bilateral agreements between member states who rigorously controlled the supply of air capacity. Air fares were largely set by fixed agreements between the carriers, which acted under the patronage of the International Air Transport Association (IATA) (Butcher, 2010). In 1983, the European Commission started its deregulation initiative, the Single European Aviation (SEA) market, a policy of gradual liberalization to reshape Member State's transport networks into a competitive market environment (Graham, 1997). On a broader scale, the reform was part of the Single European Act, the EU's ambitious effort of establishing a single internal market.

The aviation deregulation was split into three separate air transport liberalization packages. The first and the second package were implemented in 1988 and 1990, entailing, among others, the allowance of multiple designations, fifth-freedom rights, and three-bounded fare zones (Breidenbach, 2020) [*Multiple*

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designations refers to the concept of one country designating more than one of its airlines to fly a particular international route. For example, nowadays multiple U.S. airlines operate flights on the same routes across the Atlantic. Fifth-freedom rights is the legal privilege of an airline from country A to fly between country B and C. For example, Air New Zealand, operates fifth-freedom flights between Los Angeles and London. Three-bounded fare zones enable airlines to supply tickets below a standard minimum fare. This concept is of particular importance for low-cost airlines, which mostly generate revenues from ancillary services instead of the classic base fare]. Although the first two packages introduced important elements for the EU's air transport liberalization, it was undeniably the third package that produced significant adjustments to the aviation market environment. Its implementation stretched over a four-year period between January 1993 and April 1997. Major changes included the harmonization of airline licensing processes, entire liberalization of ticket fares, and the abolition of capacity regulations between member states (Graham, 1997). In sum, under the new environment all EU carriers gained open access to virtually every route in the European aviation market.

Typically, an airport's profitability depends on its annual passenger throughput. For example, airports with fewer than 1 million passengers per year typically struggle to cover operating costs and often only continue to exist because of government subsidies (European Commission, 2014). In 2014, the European Commission outlined in its "Guidelines on State aid to airports and airlines" that government subsidies to airports violate European competition law. Consequently, subsidies for (regional) airports were prohibited. While larger airports had to operate self-sufficiently at once, smaller airports, with less than 3 million passengers per year, were granted a ten-year grace period until 2024 to adapt to the changes. Although very small airports, with passenger volumes below 200,000 per year, are exempt from this directive, the new guidelines are expected to have far-reaching implications. It is estimated that more than 50% of all airports within the EU operate on state aid (Grimme et al., 2018). Additionally, the current ramifications of the global COVID-19 pandemic further accelerate the situation such that many regional airport operators are set to face existential problems in the near future. Against this backdrop, the main research objective is twofold: First and foremost, it is imperative to understand how and to what extent regional airports affect their adjacent local economy. In other words, what is the link between the existence of a regional airport and its local economic development? Secondly, these findings need to be put into context to make a judgement on the hitherto existing government subsidies. What is the economic impact of a regional airport and to what extent may these subsidies be justifiable?

Estimating the economic effects of air transport infrastructure is challenging because of a strong interdependence between infrastructure investments and regional development. Economically thriving regions usually tend to invest more in infrastructure to further stimulate regional economic development (Breidenbach, 2020). Thus, the main challenge is to isolate the causal effect of transportation infrastructure on economic growth. To overcome these challenges in identifying the relationship between air transport infrastructure and regional economic growth, a quasi-natural research design is employed by relying on the exogenous nature of the Single European Aviation market reform of 1997. Using a difference-in-differences (DiD) design [*The DiD approach is a commonly used statistical method to establish causal inference when randomization is not possible. The main idea of the DiD identification relies on mimicking an experimental setting by finding equivalents of 'treatment' and 'control group'. Its key assumption relies on the notion that observed differences between treatment and control groups are time-invariant (The World Bank, 2022).*], areas with regional airports versus areas without regional airports are compared, both before and after they qualified as regional airport areas (based on their passenger numbers), to estimate the average treatment effect of regional airports on the local economy.

This paper proceeds as follows. Section 2 discusses the related literature on infrastructure, airports, and economic growth. Section 3 introduces the data and the applied methodology. Section 4 reports and discusses the main results of the analysis, including estimation results, various sample specifications, and sensitivity analyses. Section 5 concludes the paper.

2. Related literature

This research contributes to three main branches of the literature. First, it relates to the overall literature of linking infrastructure investments and economic growth. Infrastructure investments are widely acknowledged to play a vital role in the transportation sector and economic growth as a whole (Magazzino & Maltese, 2021). Particularly transport infrastructure improves connectivity between firms, workers, and customers (Li et al., 2020). Advanced infrastructures enable goods and services to move freely from one area to another and are a distinct condition for a functioning transport system. While congestion slows down productions and overall economic growth, mobility is the foundation of resilient nations (Rietveld, 1989). Unsurprisingly, expenditure on transport infrastructure very often amounts to a significant share of public expenditures (Farhadi, 2015). This paper's main finding supports the view that infrastructure investments have positive effects on local GDP, employment, and population growth.

Second, this research contributes to the airports-economic growth nexus literature. Predominately, the relationship between aviation and economic development is seen positively, however, the extent and underlying driving forces are by no means clear. Particularly regional pre-conditions are likely correlated with the existence of an airport, resulting in biased estimates. In other words, since the choice of an airport construction is not random, it can be expected that the location of an airport is more likely to be in regions with overall greater (expected) economic prosperity. There are several non-academic studies that examine the linkage between airports and economic growth [*Aviation advocates such as IATA or the Air Transport Action Group (ATAG), tend to emphasize the role of air traffic growth as an economic catalyst for a region, by means of increasing connectivity and therefore commerce and employment (see e.g. IATA (2019) or ATAG (2018)). However, it quickly becomes apparent that these estimates suffer from omitted variable bias due to a lack of a convincing identification strategy (see e.g. InterVistas (2015) or Lieshout et al. (2015))*]. The notion of spillover effects from aviation to the local economy has also received significant attention in the academic literature, although most of these analyses focuses on large metropolitan areas. For example, Brueckner (2003) estimates the effect of air travel on production in U.S. metropolitan areas. By using the distance from the population center and the airport's hub status for a major commercial airline as an instrumental variable, he shows that air traffic growth has a positive impact on employment in service-related industries but no significant effect on manufacturing employment [*It is questionable whether the instrument is truly valid since the location of an airport hub may not necessarily be exogenous but instead the result of a deliberate choice by an airline to be located in a geographically advantageous location.*]. In a later analysis, Green (2007) tests whether the activity at a metropolitan area's airport predicts population and employment growth. Using an airport's physical size as well as industry level employment figures as instruments, he finds a positive relationship. Blonigen and Cristea (2012) exploit the variation of long-run growth rates around the 1978 U.S. Airline Deregulation Act as a source of variation in air traffic levels. They find a positive effect of airports on growth, with the magnitude of the effects differing by metropolitan size and industrial specialization. Sheard (2014) instruments for the distribution of airports, using a legislation that enabled federal funding for the construction and improvement of airports. He finds improved air service to have a positive effect on the size of the local service sector, but no effect on non-tradable services. Campante and Yanagizawa-Drott (2018) study the impact of international long-distance flights on the spatial allocation of economic activity. Using satellite-measured night lights, they show that airport expansions have a positive effect on local economic activity.

Third, this paper contributes to the underdeveloped literature on the effects of regional airports on local economic development. Debbage (1999) examined the linkage between airport operation and the structural composition of the regional economy in North and South Carolina. Although he finds that areas with significant increase in air passenger volume achieved employment gains, he does not address the issue of causality in his analysis. Yao and Yang (2008) show by means of an extensive panel data analysis that regional airport development in China is positively related with regional economic growth. A recent paper by Breidenbach (2020) offers a promising approach to measure the economic effects of regional airports in Germany. The author's identification strategy relies on exploiting the SEA market liberalization in the EU as a quasi-natural experiment, similarly to Blonigen and Cristea (2012) in the United States. He employs a DiD estimation by comparing regions with and without regional airports before and after the market reform was in place. Likely due to a lack of statistical power, the author finds no evidence that the expansion of regional airports in Germany generated regional growth. It remains unclear why the author limited the analysis to merely one country despite that the market reform affected the European Union as a whole. This research builds on and extends the methodology of Breidenbach (2020) and significantly expands the geographic scope of the analysis. To the best knowledge, this paper is the first attempt to investigate the relationship between regional airports and local economic development on a Pan-European level. Other papers have used similar regional administrative datasets, for example Percoco (2010) who studies airport activity and local development in the Italian context, but the focus remained on a country level. Finally, this paper also complements previous research that investigated the EU market liberalization from a pure transportation perspective, such as, Laurino and Beria (2014) who investigate at the relationship between LCCs and secondary airports in Italy in the context of the EU market deregulation.

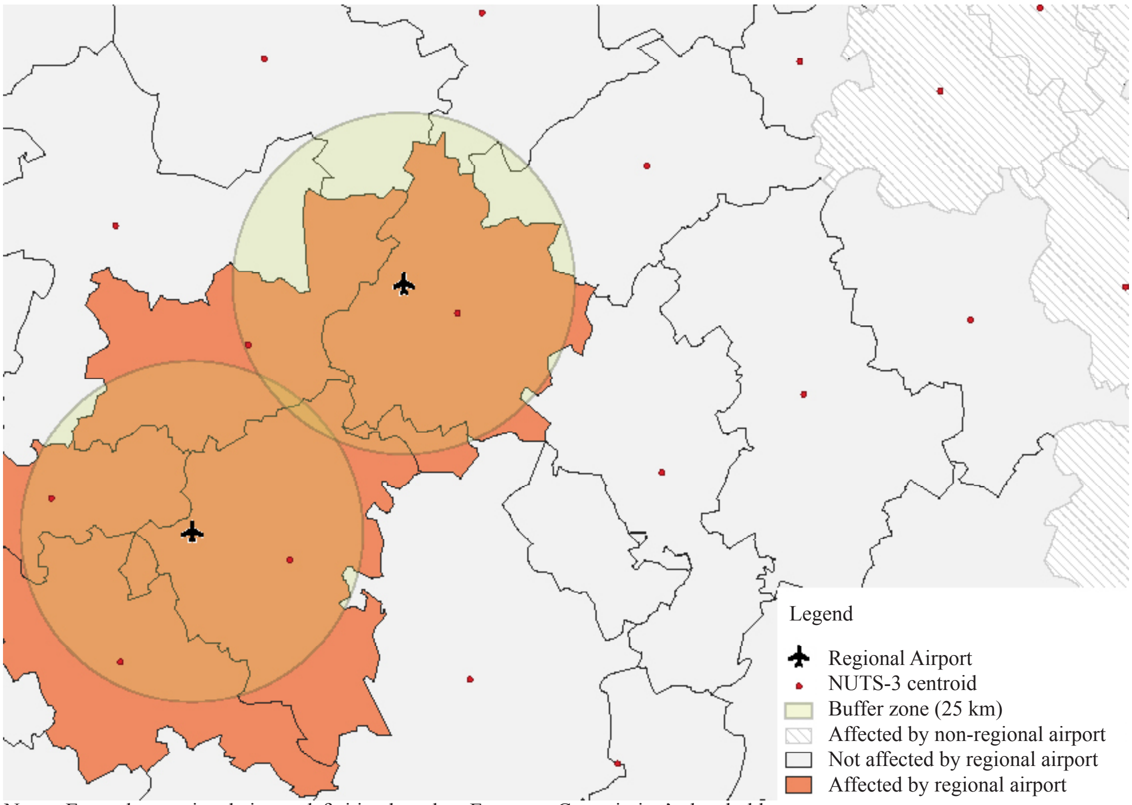
3. Data and methodology

3.1 *Data*

The panel data set consists of three pillars: Firstly, current and historical data on all commercial airports in the European Union were collected, containing information on location, size, as well as construction year and purpose. The airport data set is a combination and manual cross-check from local airport statistics as well as the publicly available data set from the website www.ourairports.com. Defining which of these airports constitutes a regional airport, is by no means clear. While some studies link the notion of a regional airport to the fact that the catchment area of an airport is located outside a major city, there is no common definition at an EU level to date. Given the context of expiring EU state aid for airports, the European Commission's (EC) subsidy ceiling of 3 million passengers per year is used as an upper boundary. Airports below the 3 million passenger threshold are defined as regional airports, while airports above this threshold are considered as non-regional airports. Hence, in the panel data an airport can be first defined as regional and at a later stage as non-regional, if it surpasses the 3 million passenger threshold [*The share of commercially active regional airports declined from over 90% in 1980 to about 75% in 2016.*]. As robustness checks, passenger thresholds of 2 and 1 million passengers per annum are also used. Secondly, Eurostat administrative level data on regional socio-economic activity is compiled, containing NUTS-3 level data on local GDP, population, and employment, ranging from 1980 until 2016 [*NUTS-3 (Nomenclature of Territorial Units for Statistics) corresponds to the most granular spatial unit, primarily used for socio-economic analyses of small regions.*]. Thirdly, satellite-generated data on terrain elevation is processed to estimate the extent of aviation-related usable land in the EU-15. Terrain ruggedness is related as a constraining factor to the development of (regional) airports. To do so, the standard deviation of elevation is computed to control for ruggedness, as well as the average height of a particular area, both measured at a 2.5 km radius around the centroid of each NUTS-3 polygon. The satellite images are obtained from the EU Digital Elevation Model (EU-DEM), provided by Copernicus Land Monitoring Service.

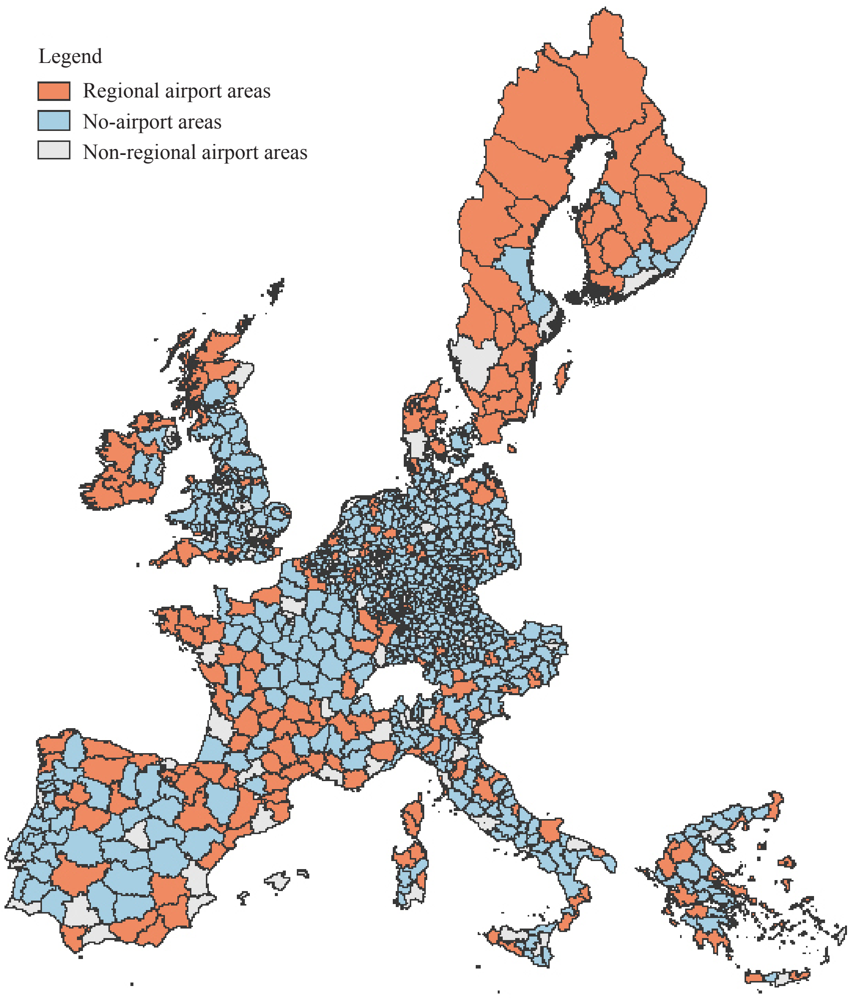
To combine the data sets, the airports' location is matched with the respective NUTS-3 region. For the analysis, NUTS-3 regions containing an airport are considered to be affected. However, likely the presence of an airport also affects variables of interest across space, meaning that regions that do not inhibit an airport but are near one, are still affected by its activity. To account for such spillover effects, the distance from the centroid of each NUTS-3 region to the nearest regional and non-regional airport is computed. If the centroid of a particular NUTS-3 region is located within a certain proximity to a (regional) airport, the regional unit was considered as affected by the airport, while the remaining regions are considered to by unaffected. When a particular NUTS-3 region is affected by both a regional and a non-regional airport, the more conservative measure was chosen, that is the region was classified as a non-regional airport region. The exact distance threshold that classifies NUTS-3 regions into affected and unaffected areas is discussed in detail in section 4.3. Figure 1 illustrates this concept graphically using a 25 km buffer zone. Each NUTS-3 centroid that falls within the radius of a regional airport, is considered as 'affected' by the regional airport. In this exemplary excerpt, five NUTS-3 fall under this category (highlighted in orange color). The second category of regions are NUTS-3, which centroid is not encompassed by the buffer of a regional airport (highlighted in gray color). Finally, some NUTS-3 regions are excluded from the specification if their NUTS-3 centroid already falls within the buffer of a non-regional, i.e., international airport (highlighted in hatched gray).

Table 1 summarizes the key descriptive statistics across the EU-15 for regions that are either affected or unaffected by regional airports between 1980 and 2016. The dedicated buffer zone to capture spillover effects is 25 km while the threshold that classifies an airport into a regional airport is 3 million passengers per year or less, in line with the European Commission's definition. Note that NUTS-3 regions containing or being adjacent to a non-regional airport (under a 20 km buffer definition) are excluded, since the aim of the paper is to solely analyze the economic effects of regional airports. On average, regions that are affected by regional airports tend to have higher levels of economic activity, measured by total GDP in Purchasing Power Standards (PPS). Also, employment, total population, and population density are on average higher in those regions. Furthermore, the average elevation in a 2.5 km radius around the centroid of each NUTS-3 region is compared to capture possible geographic constraints for construction. Regions unaffected by regional airports exhibit on average higher elevations, including a higher degree of ruggedness, expressed by a higher standard deviation, than regions that are affected by regional airports. By construction, NUTS-3 regions affected by regional airports have a smaller mean distance from their centroid to the nearest regional airport. Note that the mean and max value are larger than the defined 25 km buffer in the regions that are affected by regional airports. This is because NUTS-3 regions containing a regional airport, but its centroid is not encapsulated in the 25 km buffer zone, are still considered as affected. This distinction is important for large rural areas such as in northern Scandinavia where regional airports are scarce but still affect the sparsely inhabited region. Lastly, affected NUTS-3 areas are on average further away from the nearest non-regional airport than unaffected areas, indicating the importance to control for this variable. Figure 2 summarizes this allocation between affected NUTS-3 regions and unaffected NUTS-3 regions graphically. The quantity and size of NUTS-3 regions differs significantly among countries in the EU-15. For instance, Germany contains most of the NUTS-3 regions, however, also the smallest. In contrast, for example the Scandinavian countries encompass fewer but larger NUTS-3 regions. Overall, there are more no-airport than regional airport areas in the EU-15, based on the discussed concept of Figure 1. These NUTS-3 areas are mostly located in the central and less populated areas (highlighted in blue color). On the other hand, regional airport areas are often located in popular tourist areas, such as the South of France or Italy, or in areas with a sizable local demand but below the defined threshold of an international airport, for instance in northern Spain or France (highlighted in orange color). Finally, note that most non-regional airport areas, that is NUTS-3 areas that inhibit an international airport, are primarily located around the capitals and the most populous areas of each member state (highlighted in gray color).



Notes: Exemplary regional airport definition based on European Commission's threshold.

Figure 1. NUTS-3 regions and airport buffer zones



Notes: Based on 25 km buffer zone and EC regional airport passenger definition in 2016.

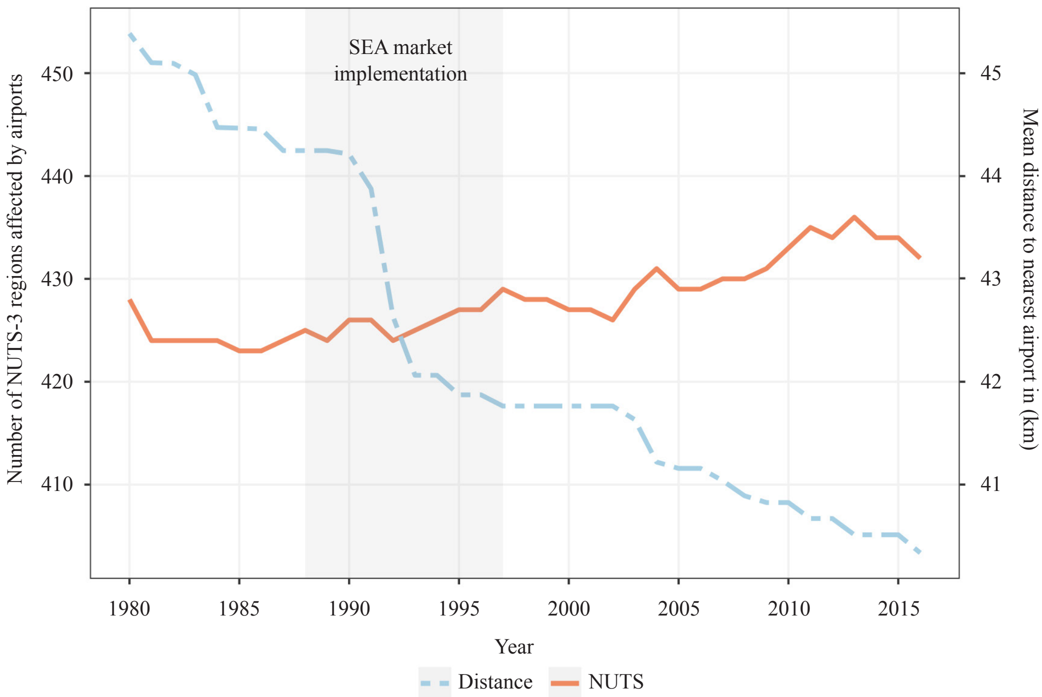
Figure 2. EU-15 NUTS-3 treatment vs. comparison group

Table 1. Descriptive statistics: treatment versus comparison group

	Regional airport areas				Non-airport areas			
	mean	sd	min	max	mean	sd	min	max
log(GDP)	22.24	1.05	16.81	25.02	21.85	0.86	17.73	25.32
log(employment)	11.65	0.91	7.05	13.88	11.28	0.71	8.11	13.88
log(population)	12.53	0.88	8.84	14.95	12.14	0.71	9.66	14.21
log(population density)	5.15	1.65	0.61	9.44	5.09	1.18	2.18	8.93
log(elevation)	4.83	1.32	-0.25	7.37	5.12	1.38	-2.89	7.59
Distance regional airport (km)	22.30	15.69	1.87	111.94	66.71	29.93	25.02	187.89
Distance non-regional airport (km)	161.24	120.01	21.38	826.33	106.92	78.15	20.13	582.83
Number of observations	11,781				24,732			

Notes: Based on 25 km buffer zone and EC regional airport passenger definition.

Figure 3 displays the relationship between the introduction of the SEA market reform and the growth of airports in the EU-15. Most notably, the number of NUTS-3 regions affected by an airport began increasing since the SEA implementation phase in the mid-1990s (orange line). Either smaller airports were converted into airports with commercial operations or entirely new airports were constructed during this period. Not surprisingly this surge in airports also resulted in better connectivity of the NUTS-3 regions across the EU, depicted by a decreasing average distance to the next airport (dashed blue line).



Notes: Based on 25 km buffer zone and EC regional airport passenger definition.

Figure 3. Number of EU-15 NUTS-3 regions affected by airports

3.2 *Methodology*

Although the nature of the panel data set permits adding time and region fixed effects to control for time-invariant characteristics, one would still neglect possible endogeneity concerns. Most prominently, major capital investments into infrastructure such as airports are usually no coincidence but instead the outcome of a deliberate economic decision to serve the existing and future economic needs of a region, resulting in a biased estimate. To overcome this, it is assumed that the unobserved differences between treatment and comparison groups, in the absence of the treatment, are the same over time. In this case, when comparing the difference of treatment and control groups before and after receiving the treatment, the average treatment effect is estimated.

In this context, a DiD methodology is suitable to estimate this effect. Following a similar methodological estimation approach by Dröes and Koster (2016), $Y_{i,t}$ represents the economic activity, measured by GDP, population, or employment levels of NUTS-3 regional unit i in year t. $A_{i,t}$ is a binary indicator variable that that equals one in years t when an airport's passenger volumes are within the European Commission's defined range of regional airports and within d kilometers of NUTS-3 regional unit i. v_i is the treatment versus control group dummy, where the treatment group are those NUTS-3 units within d kilometers of a regional airport. The basic DiD model can hence be formulated as:

$$\log Y_{i,t} = \alpha A_{i,t} + \gamma v_i + \lambda_t + \varepsilon_{i,t}, \quad (1)$$

where α captures the average treatment effect, λ_t captures year fixed effects, and $\varepsilon_{i,t}$ is an identically and independently distributed error term. In the main specification, a distance of $d = 25$ km is assumed, which is later on pressure tested with various robustness checks (see section 4.3).

There are two sources of identifying variation to measure the treatment effect. Firstly, the difference in economic activity between regions within versus outside the 25 km buffer around a regional airport is compared. Secondly, because not all airports are in existence at the same time or meet the necessary passenger volumes to classify as a regional airport, the difference in economic activities is compared in areas that have a regional airport versus areas without a regional airport at that point in time but will be classified as one at a later stage.

To control for differences in the regional economic composition of the control and treatment group, relevant control variables are added to the specification:

$$\log Y_{i,t} = \alpha A_{i,t} + \beta C_{i,t} + \gamma v_i + \lambda_t + \varepsilon_{i,t}, \quad (2)$$

where $C_{i,t}$ is a set of regional (economic) controls such as distance to the nearest non-regional airport, sectoral employment shares, and geographic construction constraints, measured by terrain ruggedness.

Since airports are not randomly distributed across space, for instance as they may be more likely to be constructed in areas with an existing economic need, one might be concerned with selection bias. This, however, should be captured by the constructed treatment group dummy variable v_i. Yet, there are likely also other unobserved factors (e.g., public service obligations that require the construction of an airfield in certain remote areas) that also affect regional economic activity. To a large extent, these factors are time invariant, allowing to control for them by using region-specific fixed effects:

$$\log Y_{i,t} = \alpha A_{i,t} + \beta C_{i,t} + \gamma v_i + \mu_i + \lambda_t + \varepsilon_{i,t}, \quad (3)$$

where μ_i represents the fixed effect for a respective NUTS-3 regional unit. Employing regional fixed effects helps to deal with all unobserved time-invariant spatial attributes that may cause the location of a regional airport to be correlated with $\varepsilon_{i,t}$. Although the NUTS-3 classification is the most granular level for socio-economic analyses of small regions, there is a substantial difference in the size of the NUTS-3 regions per country (see Table A1 in the Appendix).

While it is not possible to adjust for the difference in the unit of analysis, it may make sense however to account for unobserved local trends (e.g., local strategic policies) that are correlated with the presence of a regional airport. To do so, equation (3) is estimated using restricted sample within a relative short distance (50 km) around each regional airport [*This is also tested with even smaller values i.e. a more restricted sample. However, under these restrictions the variable regional airport presence becomes omitted as it is probably collinear with the fixed effects of the model.*]. This leads to a smaller sample size, but it addresses the issue of unobserved trends. One might also expect that the economic effect of regional airports becomes less pronounced for NUTS-3 regions that are located further away from the airport. Therefore, the treatment effect is altered over different distances from the nearest regional airport:

$$\log Y_{i,t} = \sum_z \alpha_z A_{i,t,z} + \beta C_{i,t} + \gamma v_i + \mu_i + \lambda_t + \varepsilon_{i,t}, \quad (4)$$

where $A_{i,t,z}$ equals one if it meets the passenger volume classification as before and is located within the corresponding band z. Essentially, the 50 km radius (restricted sample) is split around a regional airport into buffers (up to 15 km, up to 17.5 km, etc.), where the remainder serves as the reference group. Methodologically, it is tested at which point the cut-off value α_z yields to statistically insignificant results, relative to the reference group. Note that the main assumption is that the effect of the reference group is zero.

Finally, one would expect the effect to differ before and after the airport is defined as a regional airport. The construction or announced expansion of an airport is usually known some time before, meaning that regional economic activity could have already incorporated this information prior. This will imply a possible underestimation of the causal effect if anticipation effects were not considered. Since the variable $A_{i,t}$ changes at different times in different NUTS-3, in the spirit of Granger (1969), the idea is to perform a causality test where past $A_{i,t}$ predict $Y_{i,t}$, while future $A_{i,t}$ do not (Angrist & Pischke, 2009). In other words, the key assumption underlying a DiD strategy is the presence of a common trend between the treatment and control group (common trend assumption). This assumption cannot be tested, but, it is common practice to examine this concern by undertaking an event study to show that there is no statistically significant effect before a NUTS-3 region was affected by a regional airport, which suggests (but does not prove) that the common trend assumption holds. Methodologically, this concept can be expressed by:

$$\log Y_{i,t} = \sum_{s=\underline{t}}^{t-1} \alpha_s A_{i,s} + \sum_{s=t}^{\overline{t}} \alpha_s A_{i,s} + \beta C_{i,t} + \gamma v_i + \mu_i + \lambda_t + \varepsilon_{i,t}, \quad (5)$$

where $\underline{t}$ is first year when to expect anticipation effects, while $\overline{t}$ represents the last year for which to expect adjustment effects. $A_{i,s}$ equals one when the NUTS-3 area is considered as treated in year s and zero otherwise. Therefore, the first sums term represents the anticipatory effects of an airport construction or expansion while the second sums term captures the post-treatment effects after a particular NUTS-3 area contains or is affected by a regional airport. For this analysis, a time window of ten years before and five years after a NUTS-3 region is affected by a regional airport is used, that is $\underline{t} = t - 10$ and $\overline{t} = t + 5$.

4. Results

The results section is organized along the twofold objective of this research: Firstly, it is essential to understand how and to what extent regional airports affect their adjacent local economy. To do so, a rigorous process of various sample specification and estimation techniques is traversed to establish a convincing range of point estimates of this effect (section 4.1). Secondly, these findings are put into context of expiring government subsidies by evaluating the total economic impact of regional airports in the EU (4.2). Finally, various sensitivity checks are presented to contextualize these findings (4.3).

4.1 *Economic effects of regional airports*

In order to derive a credible range of point estimates for the economic effects of regional airports, two distinct sample specifications as well as an alternative identification strategy are examined.

4.1.1 *Unrestricted sample specification*

To investigate whether the level of regional GDP correlates with the existence of an airport, a simple regression model is specified where the binary variable airport presence, which equals one if a NUTS-3 region or its adjacent locality inhibits an airport and zero otherwise, is regressed on the dependent variable of interest GDP. Note that this specification is performed on the whole data set, that is all commercially active airports EU-15. As a single control variable, the distance to the nearest non-regional airport is added. Furthermore, year and region fixed effects are added to control for heterogeneity. In column (1) of Table 2, a positive and statistically significant relationship is found between the presence of an airport and its local GDP. Holding all else equal, the presence of an airport increases economic activity on average by $\exp(0.0376) - 1 \approx 3.83\%$, in comparison to no-airport areas. In column (5) this analysis is repeated, now, by substituting the dependent variable of interest with the level of population. The estimate suggests that the presence of an airport leads to on average 1.02% higher population levels. Lastly, in column (9) the effect on employment levels is tested. The estimate indicates that airports positively affected employment levels, although the effect is statistically insignificant at the 5% level.

Table 2. DiD Estimation Results

	Log(GDP)				Log(Population)				Log(Employment)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	All airports	Regional fixed effects	Restricted sample	Military & aero club	All airports	Regional fixed effects	Restricted sample	Military & aero club	All airports	Regional fixed effects	Restricted sample	Military & aero club
Regional airport presence	0.0376***	0.0207**	0.0340**	0.0084	0.0101**	0.0048	0.0366***	0.0190***	0.0022	-0.0073	-0.0149	0.0204**
	(0.0089)	(0.0086)	(0.0172)	(0.0120)	(0.0039)	(0.0037)	(0.0071)	(0.0057)	(0.0065)	(0.0061)	(0.0126)	(0.0091)
log(dist. non-regional airport)	-0.0105***	0.0242***	0.0117***	-0.0011	-0.0050***	0.0078***	0.0072***	-0.0000	0.0059***	0.0385***	0.0304***	0.0218***
	(0.0019)	(0.0027)	(0.0042)	(0.0037)	(0.0008)	(0.0012)	(0.0017)	(0.0018)	(0.0015)	(0.0020)	(0.0031)	(0.0029)
Employment share												
Agriculture		-0.0099	0.0563	-0.0438		-0.1265***	-0.1164***	-0.0464**				
		(0.0298)	(0.0435)	(0.0404)		(0.0129)	(0.0181)	(0.0194)				
Construction		0.4694***	0.8165***	0.2904***		0.2511***	0.2042***	0.3917***				
		(0.0415)	(0.0561)	(0.0496)		(0.0180)	(0.0234)	(0.0239)				
Services		-0.1820***	-0.1607***	-0.1052*		-0.1248***	-0.1054***	0.0775***				
		(0.0428)	(0.0542)	(0.0567)		(0.0185)	(0.0227)	(0.0271)				
Industry		0.4287***	0.4317***	0.2031***		-0.0912***	0.0466**	-0.0668***				
		(0.0323)	(0.0439)	(0.0396)		(0.0140)	(0.0183)	(0.0191)				
Non-market services		-0.2105***	-0.2035***	-0.4651***		-0.1577***	-0.1239***	-0.1483***				
		(0.0311)	(0.0433)	(0.0407)		(0.0135)	(0.0181)	(0.0196)				
Elevation x Year	no	yes	yes	yes	no	yes	yes	yes	no	yes	yes	yes
Year FE	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Region FE	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Observations	38,567	33,828	18,086	18,911	39,662	34,746	18,539	19,482	38,321	33,821	17,885	18,853
Adjusted R^2	0.9868	0.9853	0.9873	0.9881	0.9960	0.9959	0.9967	0.9962	0.9885	0.9883	0.9903	0.9895

Notes: Based on 25 km buffer zone and EC regional airport passenger definition.
Standard errors in parentheses
*** p < 0.01, ** p < 0.05, * p < 0.1

The remaining columns of Table 2 focus on the main objective of this research, the effects of regional airports. Column (2) shows the regression estimates of equation (3), the standard DiD model, controlling for year and region fixed effects. Also sectoral employment shares and terrain ruggedness are added as additional control variables to account for possible regional heterogeneity. A vast body of literature has shown that urban areas with a more favorable environment tend to develop faster over time (see e.g. Saiz (2010)). In the context of airports, it is reasonable to assume that airports are constructed and expanded in areas with a more favorable geography. However, since there is no variation in elevation over time, the measure would be perfectly collinear and therefore be dropped in the estimation. Therefore, the interaction term 'Elevation x Year' is created to capture the geography's impact on regional growth. The estimate remains positive and significant at the 5% level, indicating that regional airport regions on average have approximately 2.09% higher GDP. The effect is also positive for the level of population in column (6), albeit insignificant. The results also suggest that employment in the construction and industry sector benefited from the presence of a regional airport. In contrast, the coefficients for agriculture, services, and non-market services [*Public administration, defense, education, human health and social work activities.*] show a negative sign. This effect on the local economy, however, is not necessarily causal.

Yet, there might be other unobserved traits such as changes in local aviation policies, that might be correlated with the presence of a regional airport and hence affect the estimates. To account for such trends, equation (3) is estimated using a restricted sample: affected NUTS-3 regions are compared versus a local comparison group of unaffected NUTS-3 regions, up to a distance of 50 km away from the regional airport [*Section 4.3 compares how the estimates holds by using other distance cutoffs.*]. The estimate increases to a value of approximately 3.46% for the average treatment effect on GDP in column (3) and 3.73% for the effect on population in column (7), both statistically significant at the 5 and 1% level respectively.

Despite a convincing DiD identification setup, one may raise concerns whether the location of an airport is truly exogenous, that is unrelated to the underlying economic conditions of a region. If this is not the case, then the estimates may still suffer from endogeneity. To overcome this concern, the airports' initial construction purpose is exploited, as already discussed by Breidenbach (2020). The sample is restricted to only include airports that were either initially constructed for military purposes (military air bases) or private aviation intent (aero clubs) and later converted into a civilian and commercial airport. This restriction lends additional credibility to the exogenous nature of the treated regional airport regions, since now airports that were merely constructed because of economic motives are excluded from the analysis. Under this specification, the coefficient in column (4) shrinks to a statistically insignificant value of approximately 0.84% for the average treatment effect on GDP. Also, for the effect on population levels in column (8), the effect is smaller but still statistically significant with a value of about 1.92%. Lastly, there is also a statistically significant value for the effect of regional airports on employment. The estimate in column (12) suggests a small but positive effect of approximately 0.22%.

While the estimates above represent the average treatment effect, there might be het-erogeneity due to innate regional characteristics such as local policies or legislation. In Section A.4 of the Appendix, such potential heterogeneous effect is investigated, yet it can be argued that the average treatment effect at the Pan-European level is likely the more insightful estimate in the context of evaluating the economic significance of regional airports in the EU.

4.1.2 *Military airports sample specification*

While the notion of DiD appears to be a suitable method to estimate the average treatment effect of regional airports on the local economy, one may wonder whether the above selection into equivalent treatment and comparison groups is perfectly convincing. Figure A1 of the Appendix depicts the composition of the NUTS-3 areas into treatment and comparison groups. In the above specification, NUTS-3 areas that were affected by a regional airport are compared against NUTS-3 areas that simple did not inhibit any airport. However, the key notion of finding equivalents of treatment and comparison groups in which everything apart from the variable of interest (or other things that can be controlled for) are assumed to be the same, might be violated. Possibly there are further underlying and unobserved characteristics that determined whether a region received a (regional) airport, such as a favorable geographic location. For example, rural and remote areas are per se not as attractive to an airport developer and operator as opposed to areas with an underlying economic need for an airport such as areas in proximity to urban agglomerations. Conceivably, a more convincing classification into treatment and comparison groups may be the initial construction purpose of an airport. Henceforth, regions and their adjacent surroundings with regional airports that were initially constructed for military purposes and later converted into commercial service airports are classified as the treatment group. On the other hand, the comparison group is defined as military airports and their surroundings that remained non-commercial, that is continued to operate as a military airport. All other regions, that is regions that are affected by non-regional airports or simply do not inhibit nearby airports, are excluded from the analysis. Figure A2 depicts the adapted classification into treatment and comparison areas as well as excluded areas from the analysis.

Table 3. DiD Estimation Results: Military airports

	Log(GDP)		Log(Population)		Log(Employment)	
	(1)	(2)	(3)	(4)	(5)	(6)
	Region fixed effects	Restricted sample	Region fixed effects	Restricted sample	Region fixed effects	Restricted sample
Regional airport presence	0.0225**	0.0625**	0.0111**	0.0140	-0.0076	-0.0056
	(0.0110)	(0.0287)	(0.0047)	(0.0117)	(0.0078)	(0.0156)
log(distance non-regional airport)	0.0126***	-0.0045	0.0018	-0.0213***	0.0263***	-0.0104***
	(0.0032)	(0.0063)	(0.0014)	(0.0026)	(0.0023)	(0.0038)
Employment share						
Agriculture	-0.1452***	0.1698**	-0.1957***	-0.0983***		
	(0.0365)	(0.0664)	(0.0158)	(0.0269)		
Construction	0.3444***	0.4238***	0.2476***	0.2706***		
	(0.0463)	(0.0737)	(0.0202)	(0.0300)		
Services	-0.2119***	-0.0925	-0.1044***	0.0505		
	(0.0499)	(0.0844)	(0.0216)	(0.0342)		
Industry	0.3480***	0.1241**	-0.1523***	-0.0286		
	(0.0378)	(0.0613)	(0.0164)	(0.0249)		
Non-market services	-0.3549***	-0.3976***	-0.2327***	-0.1114***		
	(0.0360)	(0.0669)	(0.0157)	(0.0273)		
Elevation x Year	yes	yes	yes	yes	yes	yes
Year FE	yes	yes	yes	yes	yes	yes
Region FE	yes	yes	yes	yes	yes	yes
Observations	26,300	7,833	27,015	8,045	26,212	9,860
Adjusted R^2	0.9860	0.9886	0.9960	0.9974	0.9892	0.9916

Notes: Based on 25 km buffer zone and EC regional airport passenger definition.
Standard errors in parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 3 contains the regression estimates based on equations (3) and (4), now under the more restricted military construction purpose sample. Note that the sample size shrinks due to the novel classification of treatment and comparison group, in contrast to the results from Table 2. Based on the region fixed effects specification, the effect of a regional airport on GDP is about 2.28%, similar in magnitude to the estimate of Table 2, column (2), statistically significant at the 5% level. While the average treatment effect on GDP jumps to more than 6% for the restricted sample specification, it should be noted that the sample size has also been drastically reduced. Furthermore, a statistically significant average treatment effect of 1.11% on population levels is found under the model specification of column (3). The effect becomes however insignificant under the restricted sample specification of column (4). Finally, there is no statistical effect of regional airports on the level of employment.

4.1.3 *Identification revisited: Bartik IV*

Until now, the effects of regional airports on the local economy is analyzed by using the binary variable 'regional airport presence'. The results from equation (3) are informative on the average treatment effect of regional airports on the local economy. Yet, additional insights might be revealed by exploiting the information of a continuous variable $P_{i,t}$, representing the actual number of passengers. However, simply using it as an independent variable is problematic since it is highly endogenous with the dependent variables 'GDP', 'Population', and 'Employment'. To address this concern, an instrumental variable (IV) approach is applied. The instrument, denoted by $Z_{i,t}$, is defined as the interaction between the base year's passenger numbers and the EU-15 level passenger growth rate. This methodology, also known as a Bartik IV, has been widely used across many fields in economics, regional science, political economy, and urban studies (see e.g. Bartik (1991); Blanchard et al. (1992); Goldsmith-Pinkham et al. (2020)). Therefore the effect of the number of air passengers, $P_{i,t}$, on economic activity, $Y_{i,t}$, is estimated by using a Bartik IV approach.

The second stage is then given by:

$$\log Y_{i,t} = \delta \hat{P}_{i,t} + \beta C_{i,t} + \mu_i + \lambda_t + \varepsilon_{i,t}, \tag{6}$$

where $\hat{P}_{i,t}$ is obtained from:

$$P_{i,t} = \tilde{\theta} Z_{i,t} + \tilde{\beta} C_{i,t} + \tilde{\mu}_i + \tilde{\lambda}_t + \tilde{\varepsilon}_{i,t}, \tag{7}$$

where the ~ refer to first-stage coefficients and $\tilde{\theta}$ is the effect of the Bartik IV $Z_{i,t}$ on the continuous passenger variable $P_{i,t}$.

Table 4 summarizes the two-stage least squares (2SLS) estimation results. For both the 'region fixed effects' and 'restricted sample' specification, the instrument is strong as the F-statistic is above the rule-of-thumb value of 10. Yet, for the 'military & aero club' specification the instrument appears to be weak, reflected by a very low F-statistic, possibly driven by a smaller sample size. For GDP, specifications (1) and (2) yield to a positive and statistically significant effect. Expressed in millions of passengers, each additional unit yields on average to a 2.0 to 2.7% increase in GDP. For the remaining specifications with population and employment levels as the response variable, the effect is neither positive nor statistically significant. The first-stage estimates are reported in Table A2 of the Appendix A.5.

Table 4. Bartik IV 2SLS Estimation Results

	Log(GDP)			Log(Population)			Log(Employment)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Region fixed effects	Restricted sample	Military & aero club	Region fixed effects	Restricted sample	Military & aero club	Region fixed effects	Restricted sample	Military & aero club
Passengers (in millions)	0.0203***	0.0266**	-0.9370	-0.0258	-0.0305	-0.0000	-0.0200	-0.0660	-0.0003
	(0.0074)	(0.0104)	(3.9200)	(0.0195)	(0.0282)	(0.0124)	(0.0036)	(0.0052)	(0.0023)
Distance non-regional airport	yes	yes	yes	yes	yes	yes	yes	yes	yes
Employment shares	yes	yes	yes	yes	yes	yes	no	no	no
Elevation x Year	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year FE	yes	yes	yes	yes	yes	yes	yes	yes	yes
Region FE	yes	yes	yes	yes	yes	yes	yes	yes	yes
Observations	7,937	7,469	4,049	8,125	7,640	4,159	7,779	7,294	3,989
Cragg-Donald F-Statistic	112.217	188.097	0.058	106.234	193.641	4.739	100.694	183.666	4.166

Notes: I instrument for the number of passengers by interacting the base year's number of passengers with the European level passenger growth rate. Based on 25 km buffer zone and EC regional airport passenger definition. Standard errors are reported in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

4.2 *Economic impact of regional airports*

The second main research objective is to calculate the total economic impact of regional airports on the economy to gain a better understanding of the quantitative implications of the empirical results. Table 5 reports the results of the estimation. Two types of economic impact are considered: a conservative effect of 2.1% (see column (2), Table 2) and a more optimistic estimate of 3.0% (see column (3), Table 2). In the more conservative scenario, the total economic impact of regional airports on the EU-15 economy results in approximately 41 billion Euros in 2015 when multiplying the average treatment effect of 2.1% with the share of regional airports per NUTS-3 region of 25.7% and the overall Gross Domestic Product in 2015. Under the more optimistic scenario, the total impact of regional airports amounts to approximately 60 billion Euros. On a per NUTS-3 level, this translates into an economic value generation by regional airports between 146 and 214 million Euros, depending on the economic impact scenario. Putting these figures into context, it is estimated that airlines and airports together contribute to more than 140 billion Euros to the European Union's GDP each year (European Commission, 2014). Therefore, the point estimate of regional airports' economic impact is likely expected to be closer to the conservative estimate. Note that this back-of-the-envelope calculation should be interpreted with caution. Aside from looking at the average treatment effect despite possible spatial heterogeneity, a main limitation is the partial equilibrium of the employed identification strategy. In the context of regional airports, it is assumed that individuals do not move or commute from a no-airport to an airport region. In fact, the net effect on the national economy could be zero. Therefore, future research would benefit from using a structural model approach with the goal of estimating a general equilibrium.

Table 5. Economic effect of regional airports

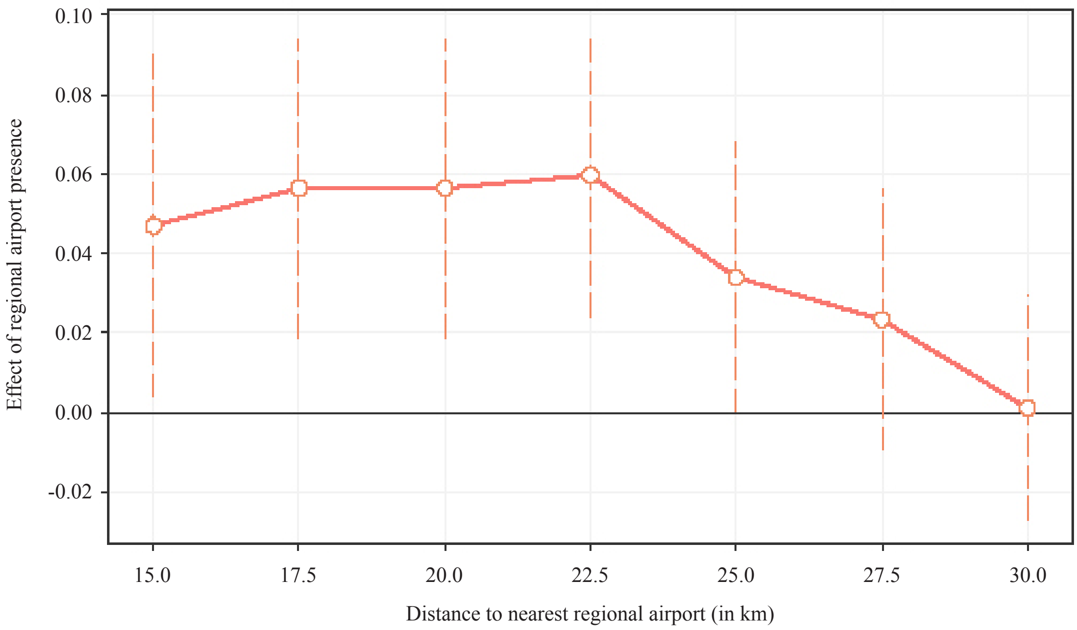
	Regional airports	
Assumed economic impact	2.1%	3.0%
Total gain (€, in millions)	40,981	60,185
Gain per NUTS-3 (€, in millions)	146	214

Notes: Based on 25 km buffer zone and EC regional airport definition. All estimates are in 2015 values.

4.3 *Sensitivity analyses*

Finally, the consistency of these results is checked by discussing the used buffer zone specification, employing an event study on the possible anticipation and adjustment effects, as well as further robustness checks on the underlying regional airports definition and timing.

4.3.1 *Buffer zone*



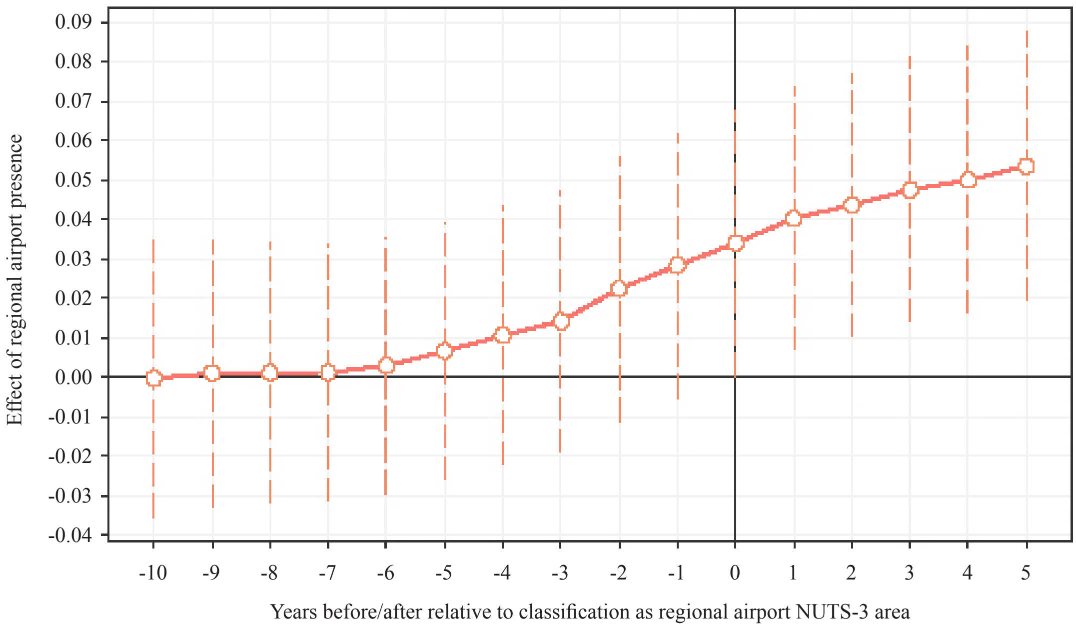
Notes: The dots depict the conditional averages per distance buffer, based on regression estimates of equation (4). The vertical lines represent 95 percent confidence intervals. Buffers below 15 km are not shown since the effect is small and statistically insignificant. The reference group contains observations that are further away than the buffer but still within 50 km of a regional airport. NUTS-3 regions within 20 km of a non-regional airport are excluded. The European Commission's regional airport passenger definition is used.

Figure 4. Treatment effect by buffer size

As outlined in Figure 1, the chosen threshold to spatially classify NUTS-3 regions into affected versus unaffected areas depends on a 25 km buffer zone. To verify whether such 25 km buffer zone is a valid choice, the treatment effect is analyzed depending on the distance, as formalized in equation (4). Figure 4 depicts the results. As one would expect, the treatment effect diminishes as the studied buffer is increased, meaning that NUTS-3 regions further away are less affected by a regional airport than regions in closer proximity. Under the smallest and statistically significant depicted buffer of 15 km the treatment effect has a value of approximately 5.0 percent. Although the treatment effect slightly increases until a buffer specification of 22.5 km, the effect then begins to rapidly decline while the 95% confidence interval begins to narrow. Under the 25 km distance specification the treatment effect has approximately a value of 4.1 percent. The results do not necessarily imply that there is no effect of regional airports beyond the 25 km buffer, but the treatment effect appears to be statistically insignificant and declining at increasing distance to the nearest regional airport. Hence, it is plausible to use the 25 km buffer zone as the preferred buffer zone choice for this analysis since it located furthest away but still yields to statically significant values.

4.3.2 *Event study*

Economic activity may already have increased in anticipation of an airport expansion or construction. Equation (5), estimates a model that decomposes the treatment effect before and after a particular NUTS-3 is considered to be affected by a regional airport. Figure 5 reports the resulting estimated coefficients. The results suggest that anticipation effects do not play a role. For instance, one year prior, the null hypothesis that the coefficient estimates are statistically significantly different from each other cannot be rejected. In the years after, the magnitude of the coefficient grows and remains statistically significant, indicating an adjustment effect. In other words, effects on economic activity appear to be persistent and larger than the baseline estimate over time (see column (3) of Table 2).



Notes: The dots depict the conditional averages for a given year, based on equation (5), before/after a NUTS-3 region is classified as affected by a regional airport under the 25 km specification. The vertical lines represent 95 percent confidence intervals. The reference group contains observations that are further away than the buffer but still within 50 km of a regional airport. NUTS-3 regions within 20 km of a non-regional airport are excluded. The European Commission's regional airport passenger definition is used.

Figure 5. Anticipation and adjustment effects

4.3.3 *Robustness checks*

Table 6. Robustness checks

	Dependent variable: Log(GDP)					
	Passenger threshold			Distance buffer		Timing
	(1)	(2)	(3)	(4)	(5)	(6)
	1 mn pax threshold	2 mn pax threshold	3 mn pax excl. < 200 k pax	75 km restriction	100 km restriction	Region x decade FE
Panel A: Unrestricted specification						
Regional airport presence	0.0445***	0.0242***	0.0353	0.0248***	0.0264***	0.0134*
	(0.0086)	(0.0085)	(0.0041)	(0.0108)	(0.0089)	(0.0072)
Distance nearest non-regional airport	yes	yes	yes	yes	yes	yes
Employment shares	yes	yes	yes	yes	yes	yes
Elevation x Year	yes	yes	yes	yes	yes	yes
Year FE	yes	yes	yes	yes	yes	yes
Region FE	yes	yes	yes	yes	yes	yes
Observations	31,812	33,162	33,864	26,460	30,662	33,857
Adjusted R^2	0.9841	0.9845	0.9846	0.9862	0.9856	0.9967
Panel B: Military airports specification						
Regional airport presence	0.0124	0.0125	0.0346***	0.0367***	0.0159	0.0122
	(0.0120)	(0.0121)	(0.0041)	(0.0153)	(0.0129)	(0.0096)
Distance nearest non-regional airport	yes	yes	yes	yes	yes	yes
Employment shares	yes	yes	yes	yes	yes	yes
Elevation x Year	yes	yes	yes	yes	yes	yes
Year FE	yes	yes	yes	yes	yes	yes
Region FE	yes	yes	yes	yes	yes	yes
Observations	24,939	25,268	26,336	12,882	17,531	26,330
Adjusted R^2	0.9857	0.9857	0.9853	0.9877	0.9875	0.9968

Notes: Based on 25 km buffer zone and EC regional airport passenger definition.
Standard errors in parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

The following section summarizes and discusses the most important robustness checks. The results of the robustness checks on GDP are reported in Table 6, while checks on population and employment as the dependent variable are reported in section A.6 in the Appendix. First and foremost, it is sensible to check the seemingly arbitrary European Commission's passenger threshold that classifies airports into regional versus non-regional airports. Note that up to now, the three million annual passenger traffic figure has been consistently used as a ceiling to define an airport as regional, or if above as non-regional. In column (1) of Table 6, this threshold is lowered to 1 million passengers per year. Now only airport areas that inhibit airports with a traffic of up to 1 million passengers annually are defined as regional airports. All other airport areas with larger airports are considered non-regional airports and are hence excluded from the analysis. Under this more restrictive regional airport definition, the coefficient of interest increases to approximately 4.55%, statistically significant at the 1% level, compared to the baseline of 2.09% of column (2) in Table 2. Under the 2 million regional passenger definition in column (2) of Panel A, the coefficient of interest with a value roughly 2.45% is again closer to the baseline coefficient. Panel B repeats these robustness checks, now for the restricted military airports sample of section 4.1. Here, the coefficients of column (1) and (2) are both lower than their baseline of Table 3, column (3), however, statistically insignificant. In column (3) of Table 6, a further robustness check is performed on the passenger threshold definition. Using again the European Commission's 3 million annual passenger ceiling, it now excludes very small airports from the analysis. Arguably, many small airports have a very different operating model than larger regional airports. For instance, some smaller airports only exist due to public service obligations (PSO), that is serving remote parts of the European Union by legislation instead of economic rationale. To adjust the sample for such airports as well as other smaller operating airport models, airports with an annual traffic below 200,000 passengers are excluded. Note that also the European Commission exempts airports with an annual traffic below 200,000 passengers from the proposed financing restrictions of its revised "Guidelines on State aid to airports and airlines". While the coefficient is statistically insignificant in Panel A, under the military airports' specification in Panel B, the coefficient becomes significant with a value of approximately 3.52%.

As a second main type of robustness check, the sample is adjusted based on the proximity to a regional airport. To recall, in equation (3) affected NUTS-3 regions are compared versus a local comparison group of unaffected NUTS-3 regions, up to a distance of 50 km away from the airport. Now, in column (4) and (5) of Table 6, that value is increased in 25 km increments. In Panel A, the value decreased for both restriction values to approximately 2.51 and 2.68% compared to the baseline coefficient of 3.46% in Table 2, column (3). The same trends holds true for the estimates of Panel B, although strictly statistically speaking the values appear to be less robust than their baseline estimate of Table 3, column (2).

Lastly, since the time frame of analysis spans over more than 35 years (1980-2016) and unobservables may change over time, there are possible unobserved time trends that are not captured by the year fixed effects but are correlated with the treatment effect. To address this issue, NUTS-3-decade trends are used as controls by computing an interaction term of region fixed effects for each decade. The results in column (6) indicate that the effect of regional airports on regional economic activity is about 1.35% under the unrestricted specification of Panel A, statistically significant at the 10% significance level, and about 1.23% under the military airports specification of Panel B, albeit statistically insignificant. The effect for both is lower than their baseline, which is not entirely unexpected, given that part of the treatment effect is thought to be absorbed by the NUTS-3-decade trends fixed effects.

5. Conclusion

Summarizing and taking up the main objectives of this research: Firstly, how and to what extent do regional airports affect their adjacent local economy? This paper investigated the effect of regional airports on local economic development, expressed by GDP, population, and employment levels. The results show that, on average, local economic activity increases between 2 and 6 percent due to the presence of a regional airport. Also, population and employment levels are both positively affected by regional airports. An additional IV estimation points towards a similar outcome, with each additional 1 million passengers yielding to a positive effect between 2 to 3 percent on GDP, yet no effects on population or employment levels are found. A variety of sensitivity checks suggest that the effect strongly depends on the size definition of a regional airport. Moreover, it can be shown that the effect is somewhat local and declines with increasing distance. It is further demonstrated that anticipatory effect likely did not play a significant role although the effect on GDP intensifies over time. Secondly, the overall economic impact of regional airports is examined by contextualizing these findings. Using a back-of-the-envelope calculation, the total economic impact of regional airports is estimated to range between 41 and 60 billion Euros, or between 146 and 214 million Euros on a per NUTS-3 level, depending on the employed regression specification.

The European Commission has recently announced its plans cut subsidies for regional airports, which merely exist due to substantial public funding. Since most regional airports in the EU are subsidized and the ramifications of the prevailing global COVID-19 pandemic further aggravates their situation, many regional airport operators are set to face existential problems soon. Against this backdrop, this paper is the first to find supporting evidence in favor of the existence of regional airports in the European Union, in line with findings from other countries and regions. This research has also significant implications for policymakers: while traditional subsidies violate EU competition law, local governments that seek to reap the local economic benefits of their regional airports, need to create a more beneficial environment to attract more traffic. For instance, this could be achieved via strategic route development partnerships with airlines, which could eventually boost traffic and therefore overall profitability of the airport. While this paper has shown overall positive effects of regional airports in the EU, future research should further focus on the true net effects by focusing on potential regional disparities.

Conflict of interest

Author declares no conflict of interest.

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Appendix

A.1 *Buffers*

Table A1, provides additional justification for the preferred and employed 25 km distance specification to the nearest regional airport. A simple calculation indicates that average size of NUTS-3 units significantly differs between countries. For instance, for Germany the implied average NUTS-3 unit has a radius of approximately 15 km while for Sweden it takes the value of almost 74 km. Yet, the preferred 25 km specification is in fact very close to the mean implied radius for the EU-15.

Table A1. Comparison of NUTS-3 sizes per country

	Implied average radius in km				
	min	mean	max	sd	N
Austria	11.45	26.84	38.33	6.67	35
Belgium	5.69	14.39	22.55	3.90	44
Denmark	7.64	31.14	52.49	17.53	11
Finland	21.10	67.53	177.49	34.02	19
France	5.78	41.94	163.27	15.99	101
Germany	3.37	15.37	41.83	6.86	402
Greece	4.64	26.44	45.97	10.47	52
Ireland	17.17	50.62	67.44	15.91	8
Italy	8.21	28.28	48.51	8.41	110
Luxembourg	28.74	28.74	28.74		1
Netherlands	6.39	16.35	27.70	5.55	40
Portugal	15.96	32.97	52.15	9.37	25
Spain	2.04	48.04	83.23	20.73	59
Sweden	31.07	73.56	183.58	38.39	21
United Kingdom	2.53	16.94	68.00	12.80	173
EU-15	2.04	24.81	183.58	18.60	1101

Notes: To estimate the implied average radius per NUTS-3 region, I assume that each NUTS-3 is a perfectly circular shape. Hence, the radius can be expressed by $r = \sqrt{\frac{A}{\pi}}$

A.2 *Sample specification*

Figure A1 breaks down the composition of NUTS-3 areas in the EU. First and foremost, NUTS-3 areas can be distinguished between airport areas, these are areas with an airport or in close proximity (25 km) to one, versus no-airport areas. These airport areas can be broken down by their purpose type. Firstly, regional airport areas are airports and their surroundings below an annual passenger threshold of 3 million. Secondly, airports and their adjacent areas above that passenger threshold are considered to be non-regional airport areas. Thirdly, some areas inhibit airport infrastructure, which is solely used by the military. These military air base areas are therefore considered to be commercially inactive. Finally, regional airport areas can further be broken down by their original construction purpose: that is construction occurred either because of military origin or because of a non-military origin, such as a planned airport by the local government. Figure A1 also illustrates the composition of NUTS-3 areas into treatment and comparison groups. For the unrestricted sample of section 4.1, the treatment group comprises of all commercially active regional airport areas, while the comparison group consists of no-airport areas. For the restricted sample of section 4.1, the treatment group is defined as commercially-active regional airport areas of only military origin versus the comparison group of commercially-inactive airport areas containing military air bases.

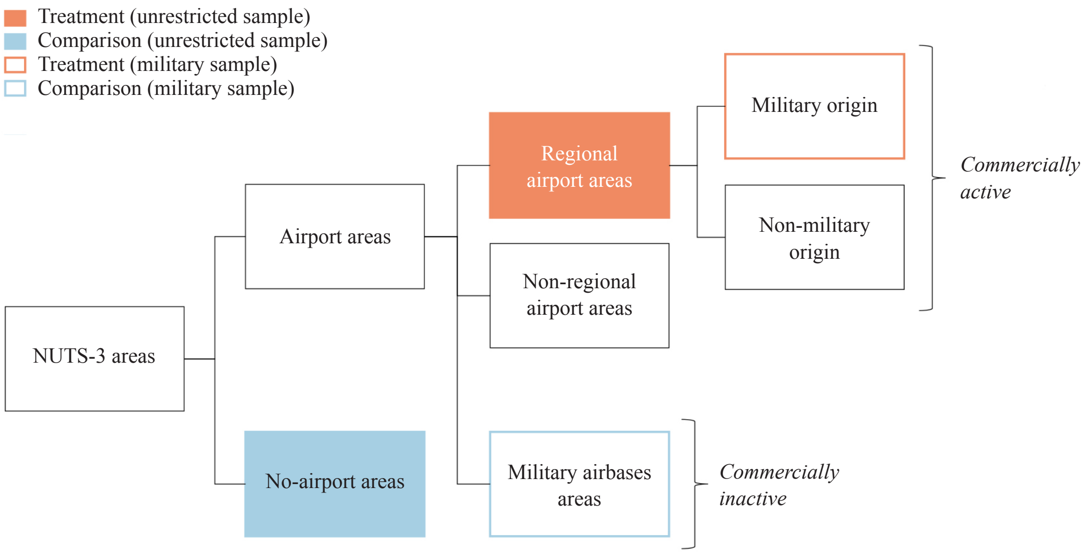


Figure A1. NUTS-3 decomposition into treatment and comparison groups

A.3 *Military airport sample specification*

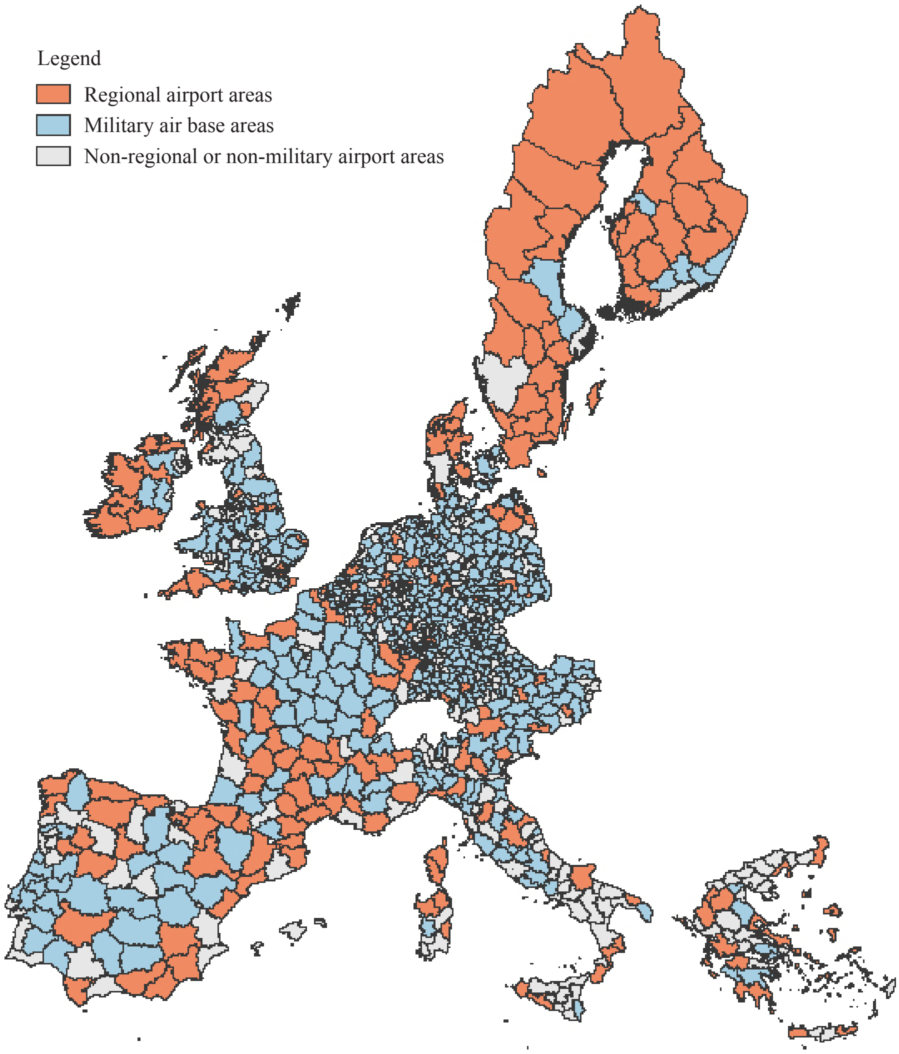
Analogously to Figure 2, Figure A2 below depicts the classification of NUTS-3 areas into treatment and comparison group, based on the military sample specification.

A.4 *Spatial heterogeneity*

There might be considerable regional heterogeneity in the effect of regional airports on the local economy. To check to what extent such heterogeneity might be present, an estimation strategy of equation (3) is applied for each country individually. The results are summarized in Figure A3. Referring to Table A1, this might already be problematic due to the mere set-up of spatial units. NUTS-3 regions are by far not evenly distributed among countries. Small countries such as Luxembourg inhibit only one NUTS-3, leading to too few observations to estimate an effect. But also, larger countries such as Sweden or Finland only inhibit relatively speaking few but large NUTS-3 regions with very little regional variation. In fact, for Sweden, Finland, Austria, and Ireland, the presence of a regional airport, appears to be collinear with the region fixed effects, leading to an omission of the coefficient of interest. Yet, for the remaining countries effects are found with considerable heterogeneity. The effect in Germany is statistically significant and appears to be somewhat higher than the average treatment effect of Table 2. On the other hand, for Greece the magnitude of the estimate is closely aligned to the average treatment effect and statistically significant. Also a positive relationship is found, although smaller in magnitude and statistically insignificant at the 5% level, for Italy and Spain. The coefficients of the remaining countries (France, the United Kingdom, the Netherlands, and Denmark) are negative but statistically insignificant, which can be attributed to random variation. Although this exercise revealed considerable spatial heterogeneity (with certain limitations), arguably the average treatment effect at the Pan-European level is more informative in order to draw conclusions with regard to the economic significance of regional airports in the EU.

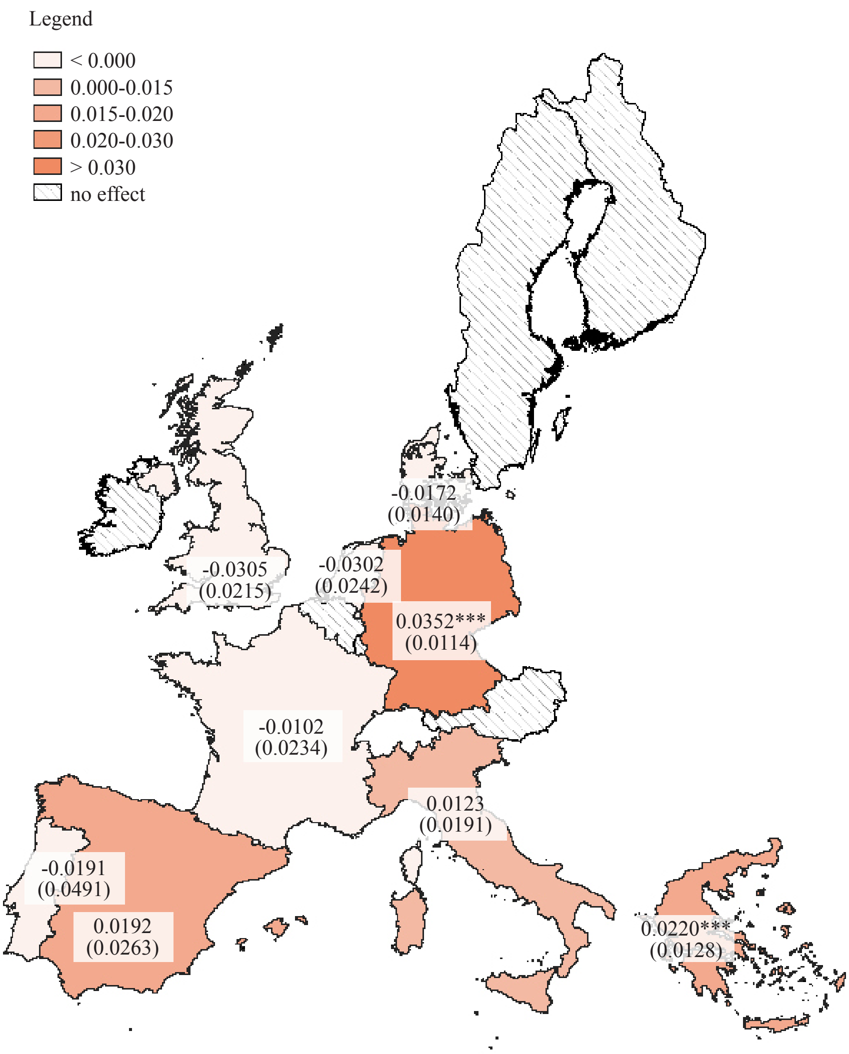
A.5 *Shift share analysis: first-stage results*

This part of the Appendix focuses on the first-stage results by checking whether the instrument is sufficiently correlated with the variable 'number of passengers'. The first-stage results are reported in Table A2. The coefficient of interest represents the Bartik instrument, that is the interaction between the local base year's passenger number with the EU-level air passenger growth rate. In both the baseline specification of column (1) and the restricted sample of column (2), a strong and statistically significant correlation is found between the 'Bartik IV' and the dependent variable. Also, the test results for both weak identification (F-Statistic) and underidentification (χ^2), using the method of Sanderson & Windmeijer (2016), implies that the Bartik IV neither suffers from a weak-instrument problem nor from underidentification. However, for the specification in column (3), the test results suggest that the Bartik IV is likely neither a strong nor a valid instrument, possibly due to the much more restricted sample.



Notes: Based on 25 km buffer zone and EC regional airport passenger definition in 2016.

Figure A2. Military airports: EU-15 NUTS-3 treatment vs. comparison



Notes: Country-level estimates are obtained from applying the estimation strategy of equation (3) for each country in isolation. Based on 25 km buffer zone and EC regional airport passenger definition. Standard errors in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1

Figure A3. Treatment effect at the country level

A.6 *Additional robustness checks*

For sake of completeness, the same robustness checks of Table 6 are also performed on population and employment levels as the dependent variable of interest. Table A3, summarizes the robustness of the results for population levels as the dependent variable. First, when decreasing the passenger threshold, the magnitude of the coefficient of interest appears to decrease as well, indicating that the effect on population level grows when considering larger airports in the specification. Also, the second main sensitivity check is in line with previous findings, that is increasing the distance buffer decreases the effect on the dependent variable, highlighting the local nature of the response. However, for the last check, using region-decade fixed effects, no statistically significant results are found. The robustness checks of the effect on employment levels in Table A4 follow the same logic, albeit the results appear to be less robust.

Table A2. Number of Passengers: First-Stage Results

	Number of Passengers		
	(1)	(2)	(3)
	Region fixed effects	Restricted sample	Military & aero club
Bartik IV	1.4710***	1.3044***	-0.0553
	(0.1389)	(0.0951)	(0.2301)
Distance non-regional airport	yes	yes	yes
Employment shares	yes	yes	yes
Elevation x Year	yes	yes	yes
Year FE	yes	yes	yes
Region FE	yes	yes	yes
Observations	7,937	7,469	4,049
S-W F-Statistic	112.22	188.10	0.06
S-W χ^2	112.33	188.31	0.06

Notes: The Bartik IV represents the interaction between the base year's number of passengers and the EU-level passenger growth rate. Based on 25 km buffer zone and EC regional airport passenger definition. Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table A3. Robustness check: Population

	Dependent variable: Log(population)					
	Passenger threshold			Distance buffer		Timing
	(1)	(2)	(3)	(4)	(5)	(6)
	1 mn pax threshold	2 mn pax threshold	3 mn pax excl. < 200 k pax	75 km restriction	100 km restriction	Region x decade FE
Panel A: Unrestricted specification						
Regional airport presence	0.0152***	0.0005	0.0129***	0.0117**	0.0145***	0.0004
	(0.0037)	(0.0036)	(0.0017)	(0.0046)	(0.0037)	(0.0024)
Distance nearest non-regional airport	yes	yes	yes	yes	yes	yes
Employment shares	yes	yes	yes	yes	yes	yes
Elevation x Year	yes	yes	yes	yes	yes	yes
Year FE	yes	yes	yes	yes	yes	yes
Region FE	yes	yes	yes	yes	yes	yes
Observations	32,639	34,024	34,746	27,110	31,433	34,739
Adjusted R^2	0.9957	0.9959	0.9959	0.9963	0.9962	0.9995
Panel B: Military airports specification						
Regional airport presence	0.0010	0.0010	0.0183***	0.0147**	0.0222***	0.0017
	(0.0052)	(0.0052)	(0.0018)	(0.0065)	(0.0056)	(0.0031)
Distance nearest non-regional airport	yes	yes	yes	yes	yes	yes
Employment shares	yes	yes	yes	yes	yes	yes
Elevation x Year	yes	yes	yes	yes	yes	yes
Year FE	yes	yes	yes	yes	yes	yes
Region FE	yes	yes	yes	yes	yes	yes
Observations	25,593	25,593	27,015	13,195	17,973	27,009
Adjusted R^2	0.9961	0.9961	0.9960	0.9969	0.9967	0.9995

Notes: Based on 25 km buffer zone and EC regional airport passenger definition.
Standard errors in parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table A4. Robustness check: Employment

	Dependent variable: Log(population)					
	Passenger threshold			Distance buffer		Timing
	(1)	(2)	(3)	(4)	(5)	(6)
	1 mn pax threshold	2 mn pax threshold	3 mn pax excl. < 200 k pax	75 km restriction	100 km restriction	Region x decade FE
Panel A: Unrestricted specification						
Regional airport presence	0.0326***	0.0036	0.0055*	0.0061	-0.0063	-0.0016
	(0.0062)	(0.0061)	(0.0030)	(0.0078)	(0.0063)	(0.0050)
Distance nearest non-region alairport	yes	yes	yes	yes	yes	yes
Elevation x Year	yes	yes	yes	yes	yes	yes
Year FE	yes	yes	yes	yes	yes	yes
Region FE	yes	yes	yes	yes	yes	yes
Observations	31,844	33,150	33,821	26,248	30,545	33,815
Adjusted R^2	0.9875	0.9880	0.9883	0.9896	0.9891	0.9979
Panel B: Military airports specification						
Regional airport presence	-0.0176**	-0.0176**	0.0115***	-0.0050	0.0031	-0.0021
	(0.0083)	(0.0083)	(0.0030)	(0.0111)	(0.0094)	(0.0066)
Distance nearest non-regional airport	yes	yes	yes	yes	yes	yes
Elevation x Year	yes	yes	yes	yes	yes	yes
Year FE	yes	yes	yes	yes	yes	yes
Region FE	yes	yes	yes	yes	yes	yes
Observations	24,835	24,835	26,212	12,642	17,274	26,207
Adjusted R^2	0.9901	0.9901	0.9892	0.9909	0.9906	0.9980

Notes: Based on 25 km buffer zone and EC regional airport passenger definition.
Standard errors in parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$