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The economic impact of aviation: a review on the role of market access

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Abstract

In recent decades, advancements in telecommunications and (air) transportation have driven globalisation processes. Consequently, policymakers and scholars view access to transportation as an essential prerequisite for economic development. For aviation, existing empirical studies have attempted to estimate the wider economic impacts from regional, country-level and global perspectives. However, no theoretical framework has yet been presented that comprehensively captures the full set of mechanisms by which aviation can contribute to economic development. Such a framework would cover both positive and negative regional impacts, as well as the mechanisms and spatial distribution behind them. In this paper, we use a New Economic Geography approach to comprehensively describe the impact mechanisms. We then apply this theoretical framework to an empirical study of metrics of air transport supply, which policymakers and researchers can use to assess how well airports and their surrounding regions are connected by means of the air transport network. The results of our analysis can inform scholars and policymakers on how air transport can shape economic geography and the productivity of economic systems. The results might also provide guidance for future empirical work on the wider economic impacts of air transportation.

Keywords: New Economic Geography, Agglomeration, Connectivity, Economic Impacts, Aviation

1 Introduction

In a globalising world, economists and policymakers are interested in the roles that geography, centrality and remoteness play in shaping the distribution of economic activity. Some scholars have claimed the 'End of Geography' (O'Brien, 1992) or 'Death of Distance' (Frances, 2001) due to significant advancements in telecommunications and transportation that have reduced the cost of interaction. For example, the real price of air freight declined by 0.5 per cent per year between 1973 and 1993 (Hummels, 2007).[1] Yet, recent evidence still points towards geography playing a substantial role in terms of shaping the distribution of economic activity (e.g. Henderson et al. (2017) and Redding and Turner (2015)). This finding is particularly significant for remote countries such as New Zealand and Australia, where the OECD's 2008 'Going for Growth' report finds that remoteness lowers average GDP per capita by 10 per cent. By contrast, the report associates the centrality of Belgium and the Netherlands with an increase in GDP per capita of more than 5 per cent (OECD, 2008).

Air transportation is the only available means of transporting passengers or goods around the globe within a single day. Therefore, it is often considered a primary driver of globalisation (Hummels, 2007). The aviation industry has grown exponentially in the last decades, driven, among other things, by per capita GDP growth and population growth (Profillidis and Botzoris, 2015). It is argued that aviation causes wider economic impacts outside the aviation industry and its value chain itself (Allroggen, 2013; Lakshmanan, 2011). Although numerous studies have empirically analysed these wider economic impacts (e.g. Campante and Yanagizawa-Drott (2018), Lakew and Bilotkach (2018) and Sheard (2019)), some methodological deficiencies make the causal relationship between aviation and the wider economy an unresolved question (Zak and Getzner, 2014).

Specifically, few efforts have been made to (i) outline the underlying mechanisms and (ii) spatial distribution of the wider economic impacts induced by aviation (Campante and Yanagizawa-Drott, 2018); and (iii) design metrics that capture how air transportation bridges distances, that is, the input that the air transport industry provides to economies (Allroggen, 2013; Lakshmanan, 2011). In practice, scholars and policymakers often rely on traffic volume metrics such as passenger numbers, cargo volume, or aircraft movements to approximate how well regions are connected through air transport systems. However, these metrics reflect market outcomes and might not capture the potential value of an air transport connection for generating market access and hence, economic impacts. In hub-and-spoke networks, for example, the economic value of flight connections to a hub airport can go beyond a single flight to the hub since the connections make numerous onward connections

[1] However, ad valorem transportation costs appear to have come down only slightly (Hummels, 2007; OECD, 2008).

available. Furthermore, often only the localised economic impact is considered; that is, the impact on the nearest region or city. Such local impacts are likely to overstate the overall economic effect of aviation as distant regions might experience smaller or even adverse effects. Lastly, most studies employ reduced-order empirical models that leave no interpretation of the underlying mechanisms.

To bridge these gaps in the literature, we (i) review the New Economic Geography; (ii) structure spatial and aspatial metric concepts for measuring the availability and quality of transport connections; and (iii) empirically compare air connectivity metrics to other metrics of air transport used in economic impact assessments. The results can help scholars and policymakers study the role of air transport networks in creating market access and wider economic impacts.

The paper proceeds as follows. Section 2 provides an overview of the present literature on the economic impact of aviation. In Section 3, we present a narrative review of the New Economic Geography (NEG) to derive a common understanding of transport- and non-transport-related interaction costs and their impact mechanisms on economic activity. Section 4 derives policy-relevant versions of the theoretical metrics from Section 3 by classifying geographical and non-geographical drivers of transport costs and subsequent market access. It further empirically compares the metrics defined in Section 4 with commonly used air traffic metrics. Section 5 concludes.

2 Review of economic impact literature

In the last 30 years, different studies have tried to assess the economic impact of aviation. Table A.1 (Appendix) provides an overview of existing empirical analyses of the wider economic benefits of air transportation.

Several studies, most of which are in the tradition of Aschauer's public capital hypothesis (Aschauer, 1989), quantify the economic impact of air transportation infrastructure (Allroggen and Malina, 2014; Cantos et al., 2005; Cidell, 2015; Cohen and Paul, 2003; Hong et al., 2011; Tittle et al., 2013). While transport infrastructure is a necessary condition for air transport connections, a lack of scheduled connections would still result in prohibitively high transfer costs for most users of today's air transport system. Since infrastructure metrics do not reflect whether such scheduled connections exist, they are only poor proxies for connectivity generated by airlines at airports.

Most analyses of the wider economic benefits of air transportation have used measures of traffic volume as impact variables. Three measures are standard in the literature: (i) passengers or seats (Sheard, 2019), (ii) cargo volume or mass (Button and Yuan, 2013), and (iii) number of flights (Fageda, 2017), either total flights or departing flights (see Table A.1). Just like infrastructure stock, these metrics do not capture transport costs or the potential of connected destinations because traffic volumes alone contain little information on the content of the exchanges being fostered (Neal, 2010). For example, a significant share of airport activity nowadays can be (outgoing) leisure travel, which does not generate wider economic impacts[2] (besides creating utility for residents). Secondly, traffic volumes cannot capture the onward connectivity created through indirect flight connections in hub-and-spoke networks. While some analyses have also leveraged airport hub status, few have used theoretically appropriate metrics of air connectivity or air accessibility in the empirical analysis. Notable exceptions are Campante and Yanagizawa-Drott (2018), Cristea and Danila (2017), Gibbons and Wu (2017), Irwin and Kasarda (1991), Ivy et al. (1995), LeFors (2015) and Yamaguchi (2007). These studies use metrics that reflect elements of modern connectivity or accessibility metrics.

Although most studies identify positive impacts on employment, GDP, productivity and population, the empirical strategies employed offer little understanding of the mechanisms behind these impacts. Lakshmanan (2011) pointed out three major drawbacks of a reduced-order approach: (i) a lack of consensus regarding the magnitude and direction of economic impacts, (ii) a lack of added understanding regarding the mechanisms linking transportation improvements and the broader economy, and (iii) the use of ill-justified functional forms that may not account for all possible impact mechanisms.

With a few notable exceptions, most studies have not looked at the spatial distribution of air transport impacts, and instead, have assumed the economic impact of each airport to accrue to the closest metropolis. Only a handful of studies, such as Campante and Yanagizawa-Drott (2018), Fageda and Gonzalez-Aregall (2017), Chi (2012) and Percoco (2010) have considered a spatial-economic perspective to distinguish between positive and (potential) adverse economic effects, including for small airports. Overly localised impact assessments—specifically with a focus on major airports and cities—fail to incorporate the complete spatial distribution of economic outcomes; that is, improvements in transportation are likely to generate contrasting impacts in nearby and remote regions. The need for a spatial-economic assessment is even higher in aviation due to the large variability in catchment areas (Lieshout, 2012). As a result, existing studies are likely to overestimate the wider economic impact of aviation and fail to provide relevant advice for regional development through small airports. One approach to capture the spatial distribution of air transport impacts involves different spatial weight matrix specifications, as is standard in the spatial econometrics literature (Elhorst, 2010).

[2] As a secondary effect, outgoing tourism at the national level can act as an import by allowing the receiving country to purchase exports from the dispatching country due to division of labour accounting for comparative cost advantages.

3 Approaches to assess the impacts of location and transportation on economic development

The previous section highlighted the importance of understanding the mechanisms behind and spatial distribution of transport-induced economic impacts. Wider economic benefits related to transportation are often considered to be caused by the 'service' of bridging distances (Allroggen, 2013; Lakshmanan, 2011). As such, they are related to concepts of spatial interaction and geography. Therefore, this section reviews the New Economic Geography (NEG) to build a framework for a better understanding of the economic impact of (air) transportation. We do not discuss the demand-side macroeconomic impacts of (air) transportation, which are often referred to as direct, indirect and induced impacts (ATAG, 2014) since they measure the significance of the sector itself, rather than the enabling impact of the sector.

3.1 Impact mechanisms and spatial scope of transport-related market access

Agglomeration economics, in its traditional form, focuses on the Marshallian types of agglomeration externalities: (i) labour pooling, (ii) (external) spillover of knowledge, innovation and technology,[3] and (iii) import and export expansion through input-output linkages (that is, access to consumers and suppliers) (Marshall, 1890), which can be rephrased as (i) matching, (ii) learning and (iii) sharing (Duranton and Puga, 2004). Traditional agglomeration economics does not explicitly take transportation into account and considers all impact mechanisms to be local externalities (either pure local externalities such as spillover, or pecuniary externalities such as input-output linkages and labour pooling). Therefore, agglomeration economics can only explain the distribution of economic activity across space under persisting or reinforcing existing spatial patterns of agglomerated externalities, such as regions that have a larger market for historical reasons (including factors such as early adoption of transport infrastructure and natural resources, sometimes called first nature). In the absence of transportation, firms in this framework maximise market access by serving every market with a share of production that depends on local factor endowments (including labour pooling, specialised suppliers and knowledge spillover) and consumer market size (*backyard capitalism*) (Eaton and Lipsey, 1976).

Building on this, New Economic Geography (NEG) presents a formal theory that sets out to analyse why and how economic heterogeneity emerges across space through treating geography as endogenous (Krugman, 1991). In his seminal paper, Krugman (1991) showed how, in the presence of internal

[3] The concept of *proximity* is used in the literature on inter-organisational collaboration and innovation (Knoben and Oerlemans, 2006).

economies of scale (imperfect competition), access to external economies of scale can lead to the spatial concentration of economic activity and people. NEG focuses on Marshall's (1890) input-output linkages associated with large markets, which act as an endogenous agglomeration force shaping a process of circular causation between workers and firms (Figure 1). NEG subsequently analyses how the location of demand is jointly determined with the location of production (Venables, 1996).

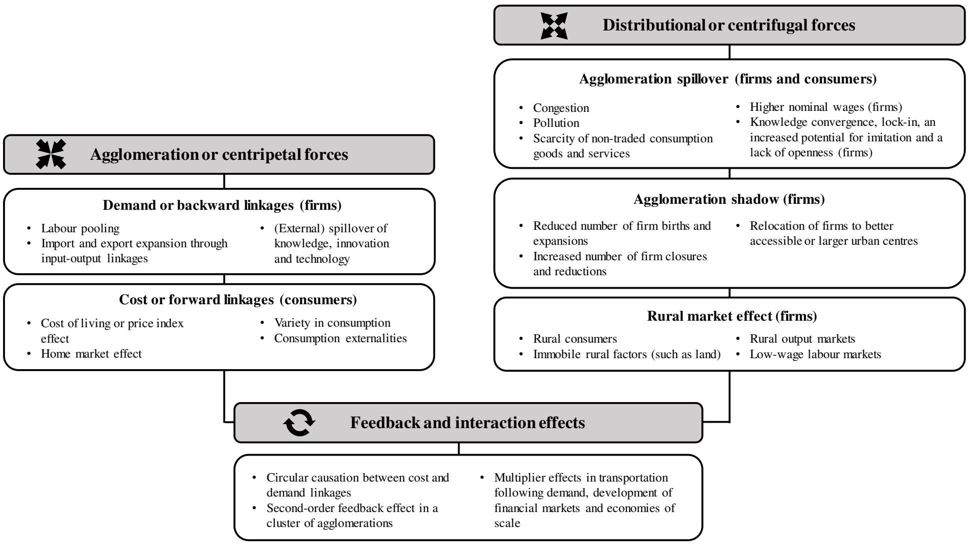


Figure 1 Overview of impact mechanisms and spatial scope of transport-related market access

In this framework, greater market access allows cities to agglomerate and become centres of economic activity, where access refers to the interaction cost incurred to reach a specific market. For aviation, interaction costs comprise both the cost of access to airports (by road or rail) and the ease of travelling through the air network (via direct or connecting flights), to which airports provide entry. To study the economic impact *of* aviation, a spatial-economic perspective is needed that looks at the ease of reaching all other airports of relevance from a specific region or city. To study the economic impact *on* the air transport industry, catchment areas are used to represent the number of (potential) passengers that are available to a specific airport. Markets can refer to demand markets (such as consumers) or supply markets (for example, suppliers, (skilled) labour) and spillover of knowledge, innovation and technology. Since transport costs form a significant portion of spatial interaction costs, they are an essential driver of market access (Anderson and Van Wincoop, 2004; Behar and Venables, 2011; Behrens et al., 2016; Glaeser and Kohlhase, 2004; Hummels, 2007). Therefore, NEG captures the impacts of transportation on economic activity and its distribution through the impact of transportation on market access. By enabling access to (external) markets, aviation can impact the economy from the regional to the global scale, thereby changing the spatial distribution of economic activity as well as productivity of economic systems.

3.1.1 Agglomeration or centripetal forces

In NEG, improvements in market access, such as through better transport links, drive agglomeration from both the business and the consumer perspective.

From the business perspective, transportation changes the strategic behaviour of firms since firms can gain access to both local and external markets by exporting outputs and importing inputs while leveraging economies of scale through agglomerating production (Venables, 1996). If either transport costs are prohibitively high or if no internal economies exist, production will converge to the backyard capitalism model following the first-nature agglomeration of externalities. With decreasing transport costs, profit-maximising firms will gradually leverage internal economies of scale by agglomerating production in locations with access to relevant markets (both internally and externally) (*demand* or *backward linkages*) (Krugman, 1991). In the latter case, profit maximisation will entail a trade-off between internal and external economies on the one hand, and transport costs on the other hand. As a result, decreasing transport costs enable firms to locate in nodes that are central to both their supply and demand networks. While this mechanism provides insights into the spatial distribution of economic activity, it can also explain changes in the overall productivity levels associated with agglomeration economies.

While NEG originally restricts itself to Marshallian input-output linkages, the concept of demand linkages extends to the spillover of knowledge, innovation and technology (Fujita, 2007). Spillovers can occur over long distances through telecommunication and transportation networks. The literature on inter-organisational collaboration and innovation views geographical proximity as neither a (strictly) necessary nor a sufficient condition for innovation diffusion thereby recognising the need to analytically isolate the effect of geographical proximity from other forms of proximity (Boschma, 2005; Knoben and Oerlemans, 2006). Despite rapid advances in communication, the diffusion and spillover of knowledge, innovation and technology still requires face-face communication (Nonaka and Takeuchi, 1995). Gaspar and Glaeser (1998) explained this through a potential complementarity between (tele)communications and face-to-face interactions. Recently, Coscia et al. (2020) explained the rapid increase in business travel between 2011 and 2016 by arguing that despite improvements in telecommunication technologies, these technologies are still inadequate for the diffusion of knowledge, especially know-how and know-who.

From the consumer perspective, transportation options can make agglomerations more attractive places of residence because consumers have an incentive to settle in cities or regions with favourable access to significant markets (*cost* or *forward linkages*) (Krugman, 1991). There are four primary reasons for this. First, highly accessible cities or regions can have a lower cost of living (price index) for goods (*cost of living* or *price index effect*), due to (i) a smaller proportion of consumption goods bearing transfer costs (Fujita et al., 1999), (ii) more competitive prices, and (iii) lower transfer costs. Second, nominal wages can be higher in regions with a larger home market due to the advantage of agglomerated production (*home market effect*) (Krugman, 1980), and more job opportunities can be available. This effect is catalysed by two factors: (i) the complementarity with other high-ability (knowledge) workers increases the productivity of workers (Davis and Dingel, 2013; Fujita, 2007); and (ii) accessible cities have higher value-added to reward workers (Venables, 1996). Together with lower price levels, these effects can result in real wage increases for more accessible cities or regions. Third, consumers value variety in consumption. Accessibility increases variety, which results in consumers' additional preference to settle in highly accessible cities or regions (Krugman, 1996). Lastly, consumption externalities may also play a role in agglomeration (Glaeser et al., 2001; Sinai and Waldfogel, 2004). As a result, the agglomeration of people is accelerated through the consumer demand effect in central nodes of economies. Hence, we expect transport-driven improvements in market access to accelerate population growth in well-connected regions.

3.1.2 Distributional or centrifugal forces

The impact mechanisms outlined above are partly distributional. As such, reductions in transportation costs can result in gains for some regions, which are fuelled by losses in other regions. There are three main reasons for this.

First, congestion and pollution can render highly agglomerated cities or regions undesirable. The scarcity of non-traded consumption goods and services (such as houses and land) may drive up corresponding prices. Furthermore, the equalisation of real wages in terms of non-traded goods and services leads to higher nominal wages, which constitutes a dispersion force for firms (Helpman, 1998). In terms of innovation, proximity may also lead to knowledge convergence, lock-in, an increased potential for imitation and a lack of openness (Boschma, 2005; Boschma and Frenken, 2010; Letaifa and Rabeau, 2013). These push forces disincentivise agglomeration, especially in congested areas. As a result, with low transport costs, these forces create a pull force for firms and workers away from the congested agglomeration into less congested but less accessible or smaller urban centres (*agglomeration spillover*). This trade-off between congestion and accessibility can lead to a process of hierarchal agglomeration, resulting in patterns of (de-)agglomeration in multiple-centre geographies (Fujita et al., 1999). Reduced transportation costs can then result in overall positive impacts by enabling firms and consumers to escape from the disadvantages of congested agglomerations. Since agglomeration spillover describes the effect of overagglomeration, it does not directly apply to transportation systems itself but rather to urban centres.

Second, when one region starts attracting firms and workers due to lower transport costs, these activities are often attracted away from less accessible regions (Krugman, 1993). Improvements in market access in one region can thus induce a reduction in economic activity in other regions (*agglomeration shadow*) (Fujita et al., 1999), either due to a reduced number of firm births and expansions, an increased number of firm closures and reductions or relocation of firms to better accessible or larger urban centres (due to diminished profitability for firms). The effect can be expected to be particularly prevalent if transport costs are reduced from prohibitively high levels since very high transport costs shelter less competitive regions, where economies are mostly depending on local demand, from competition by other regions. As such, reduced transportation costs can lead to unintended negative impacts on vulnerable economies (Krugman and Venables, 1995). As access to point transportation infrastructure (traffic intersections and terminals for sea and air transportation) is less ubiquitous than for line infrastructure (such as road and rail), the former is more likely to generate an agglomeration shadow.

Agglomeration spillover and shadow describe the impact of improved transportation in one region on another, where both regions can be close to (localised impact) or further-away from (remote impact) each other. Although both effects are expected to co-occur in practice, we can identify two extreme cases. If the agglomeration shadow effect dominates at close distances, agglomerations consist of urban centres surrounded by a rural area economically tied to their urban catchment area (hinterlands). These larger urban centres then outcompete nearby (smaller) urban centres by offering a higher level of market access. If the agglomeration spillover effect dominates at close distances, regions with high market access attract a surrounding local cluster of agglomerations (forming metropolitan areas characterised by urban sprawl), in which firms and workers enjoy high levels of accessibility through access to the local transportation network; far-away regions then act as a profiteering region.

Third, some firms prefer to be close to rural markets—including rural consumers, immobile rural factors (such as land), rural output markets, and low-wage labour markets—while serving both more rural and agglomerated areas (*rural market effect*) (Krugman, 1991). Low transport costs can enable such firms to benefit from a rural location while retaining access to large markets in agglomerated areas. Furthermore, transportation is considered to enable specialisation and economic restructuring through increasing competitive pressures in expanding markets (Lakshmanan, 2011).

3.1.3 Feedback and interaction effects

As discussed by Krugman (1991), cost and demand linkages create a system of *circular causation,* for two reasons: (i) agglomerations offer high real wages, greater product variety and consumption externalities, which attract workers (who are at the same time consumers); and (ii) the subsequent increase in the number of consumers creates a larger market, which attracts firms.[4]

Additionally, a cluster of agglomerations may induce further agglomeration through a *second-order feedback* effect (Ploeckl, 2012). By entering the cluster, an agglomeration will increase accessibility in nearby locations. This increased accessibility elsewhere will lead to the agglomeration of firms and workers, which will eventually increase the accessibility of the initial location.

Besides circular causation acting through the agglomeration of workers and firms, a reinforcing relationship might exist between economic agglomeration and transportation, especially aviation. Economic development can spur air transportation services through three mechanisms: (i) demand, (ii) financial markets, and (iii) scale economies. First, a larger (and more affluent) pool of workers and firms creates demand for air transportation services and transportation infrastructure that will incentivise transport providers to increase supply. Additionally, administrative functions, economic decision-power (for example, firm headquarters), knowledge and scientific research activities, and tourist attractiveness are likely to generate or attract air traffic (Dobruszkes et al., 2011). Second, well-developed financial markets affect airlines' ability to secure capital equity and finance debt, which are necessary to expand their networks (Tam and Hansman, 2002). Third, scale economies in transportation may lower transport costs further (World Bank, 2008). We outlined above how supply-side economic impacts from transportation occur through providing better market access. Therefore, to estimate the economic impact *of* air transportation, empirical approaches need to be considered that single out this supply-side impact from the economic impact *on* air transportation (Brueckner, 2003; Green, 2007). In sum, multiplier effects are likely associated with improvements in air transport links—beyond the often-discussed multiplier effects of demand-side economics, resulting in a circular and reinforcing association between economic indicators and aviation.

3.2 Defining outcome variables

Given the multi-dimensional nature of the mechanisms behind the NEG, no single measure best reflects the outcomes of improving market access (Head and Mayer, 2004). In theory, agglomeration processes can affect (i) productivity, (ii) wages, (iii) employment, (iv) rents, (v) population and (vi) output (Rosenthal and Strange, 2004). Many of these outcome dimensions have been used in empirical studies of the wider economic benefits of air transportation (see Table A.1).

[4] The system can still be circular in the absence of labour mobility (i) since firms are interested in consumer purchasing power, not consumers per se (Venables, 1996) and (ii) through vertical linkages between firms and industries (Krugman and Venables, 1995, 1996).

Due to the interrelatedness of these outcomes, the empirical identification of the wider economic impacts of (air) transportation faces significant challenges. First, control variables are required to account for a large number of impact outcomes (omitted variable bias). At the same time, simultaneity needs to be accounted for between the different outcomes (for example, through circular causation). As a result, the correlation between size-based measures such as employment, population and production is often too high to enable the identification of their separate effects (Combes and Gobillon, 2015).

Lastly, some authors suggest using density measures (such as employment per unit of area) to assess the impact of agglomeration (Ciccone, 2002; Ciccone and Hall, 1996). While this overcomes measurement problems associated with spatial units (Arbia, 1989), it is not clear whether agglomeration has an impact on overall levels of economic activity through increasing density. For example, the agglomeration spillover effect discussed in Section 3.1.2 may result in cities lowering density through expansion if the internal friction of transportation is low.

4 Measuring aviation-attributable market access

Section 3 discussed a theoretical framework for estimating the wider economic impact of market access with a focus on aviation. Although NEG is concerned with agglomeration and accessibility impacts, it often takes a rather coarse view of the transport system. While quantifying the actual economic impact of aviation is outside the scope of this paper, Section 4 discusses which measures might reflect best how airports connect passengers to markets through the aviation network. Designing optimal impact metrics is an important first step towards estimating the wider impact of aviation and often overlooked in empirical work.

4.1 Impacts of transportation on market access

As discussed in Section 3, market access is a central driver of (regional) economic activity in the NEG. Fujita et al. (1999) modelled market access as the level of income (that is, market size) and level of market competition at destinations over transfer costs[5]. The NEG literature has emphasised the significance of considering a broad set of transfer costs, including transport cost (Krugman, 1991), trade cost (Baldwin, 2003), and transaction cost ('the costs of doing business across space', Krugman and Venables, 1996). For industrialised countries, Anderson and Van Wincoop (2004) found transfer

[5] NEG uses an iceberg-type of transportation cost as a proxy for transfer costs. The iceberg form determines which fraction of the original unit actually arrives. The level of competition is represented by the price index of traded output (corresponding to the type of wage considered).

costs to be composed of 21 per cent transportation costs, 44 per cent border-related trade barriers, and 55 per cent local distribution costs. According to Behar and Venables (2011), freight costs account for two-thirds of the effect of distance on trade. As such, transport connections can impact on economic systems through altering transfer costs and market access in NEG frameworks.

Market access and the impacts of transportation on market access have also been studied outside the NEG literature. Market access can be considered closely related to the concept of 'accessibility'. Perhaps the earliest notion of accessibility came from Harris (1954), who calculated accessibility as the sum of retail sales over (monetary) transportation cost.[6] Hansen (1959) generalised this concept by defining accessibility as 'the potential of opportunities for interaction', thereby making both the intensity and the ease of interaction integral parts of accessibility.

Using a transportation-focused perspective on accessibility, Geurs and Van Wee (2004) decomposed accessibility into a land-use component and a transportation component. The land-use component captures both the set of economic opportunities at each destination (market size) and the competition for those opportunities (confrontation of supply and demand). The transportation component is expressed as the generalised transport cost for an individual or good to cross the distance between origin and destination, which includes (i) direct (monetary) costs (such as ticket fare), (ii) opportunity costs (such as for travel and waiting time) (Rietveld and Brons, 2001), and (iii) disutility costs (such as risk premiums, travel adjustment cost, option values, level of comfort) (Li et al., 2010). These costs are not only a function of transportation links, but also a function of geography (Redding and Schott, 2003).

In this paper, we build on Hansen's (1959) definition of accessibility ('the potential of opportunities for interaction'), but further generalise the concept to be a negative function of transfer cost to, and a positive function of the value of all destinations.[7] Destination values depend on what types of interaction are being investigated and what types of interaction are significant to the region under investigation. For example, to capture the market value of destinations for knowledge, innovation and technology spillover, we could consider the innovativeness of destinations, such as through measuring the number of patent and trademark filings at each destination, or the endowment of high-ability individuals who spend time exchanging ideas (Davis and Dingel, 2013).

Transfer costs in general and transport costs, in particular, are not only a function of institutions, infrastructure and the transportation system, but also

[6] Although Harris (1954) defined *market potential* (that is, market size over distance), he used a related measure instead (market size over transport cost). Therefore, it is important to distinguish market potential from Harris-type accessibility measures.
[7] The economic opportunities at the destination depend not only on the market value but also on the level of competition in that market.

a function of geography. In turn, transport costs can be decomposed into spatial and aspatial components. While the spatial costs capture the average cost of overcoming (linear) distance and geographic barriers, aspatial transport costs are premiums or deductions associated with the specific quality of the existing transport system (such as frequency and directness) (Lenaerts et al., 2020). This decomposition reflects the fact that transportation is an imperfect substitute for central locations.

Based on this decomposition, Lenaerts et al. (2020) proposed a classification of transport metrics that distinguishes spatial attributes (such as being land- or sea-locked, distance from economic centres) from aspatial attributes (Figure 2). In this framework, accessibility is defined as a spatial concept based on generalised transfer costs. In contrast, Lenaerts et al. (2020) defined connectivity as an aspatial concept 'which captures the quality of transport as a means to overcome distances, without considering geographical location'. This definition is judicious since it allows scholars to select transportation metrics in line with their research scope. Accessibility metrics are aggregate metrics that capture transfer costs in terms of both geography and the role of transportation as an (imperfect) substitute for central locations. They are, therefore, well suited to study the geographical distribution of economic activity and wealth. However, decision-makers cannot fully control accessibility since geography, at least in the short term, cannot be changed. Instead, decision-makers might be interested in understanding the more discretionary component of transport connections and their quality. For this purpose, aspatial connectivity metrics can be used (Lenaerts et al., 2020).

As noted above, market access is not only driven by generalised transfer costs, but also by the (potential) value of interaction at the destination. To capture this value, accessibility metrics weight each link by its relative importance, for example, measured by the quality of the links' destination (Geurs and Van Wee, 2004). In contrast, Lenaerts et al. (2020) defined destination-invariant accessibility as a measure of generalised travel costs that disregards destination quality. Similarly, they defined market connectivity metrics as aspatial measures of transportation link quality, where its relative importance weights each link; that is, based on destination quality (Figure 2). As such, transport-based market connectivity is the aspatial analogue of the spatial accessibility concept.

		Weighting of links	
		Weighted (*destination quality*)	***Invariant*** (*no destination quality*)
Spatial coverage	***Spatial*** (*generalised transportation costs*)	Accessibility	Destination-invariant Accessibility
	Aspatial (*service and infrastructure quality*)	Market Connectivity	Connectivity

Figure 2 Types of connectivity and accessibility metrics
Source: Lenaerts et al. (2020)

4.2 Measuring connectivity

Travel destinations differ in the level and types of market access they provide to air travellers (such as access to jobs and services). Similarly, routings differ in the costs that air travellers have to occur. Lenaerts et al. (2020) classify air connectivity metrics that take both destination and connection quality into account as either market feasible-links or market link-quality metrics. Feasible-link connectivity incorporates connection quality by only including feasible routings, where feasibility depends on layover time, routing factor in terms of distance and airline agreements (Doganis and Dennis, 1989; Seredyński et al., 2014). Link-quality connectivity models, on the other hand, specify a functional form to weight each connection according to its connection value to passengers, allowing a more refined assessment of connectivity. Examples of such metrics are the Bootsma (Bootsma, 1997), Netscan (Veldhuis, 1997), weighted number of connections (WNX) (Burghouwt and De Wit, 2005), Danesi (Danesi, 2006), Jenkins (Jenkins, 2011), Continuous Connectivity Index (CCI) (Lee et al., 2014) and Connection Utility (ConnUM) (Zhang et al., 2017) connectivity models. These models, however, only consider connection quality. Examples of connectivity measures that include both connection and destination quality are the Global Connectivity Index (GCI) (Allroggen and Malina, 2014) and Airport Connectivity Quality Index (ACQI) (Wittman and Swelbar, 2013). The ConnUM and GCI models apply different data-driven approaches to calibrate their model parameters. Lenaerts et al. (2020) discuss these typologies in more detail. Since we are interested in a connectivity measure that comes closest to aspatial market access (that is, incorporating both the travel cost and market value at destination), we focus on the GCI metric in the following empirical analysis.

The GCI developed in Allroggen et al. (2015) is a market connectivity metric designed to measure the quality and quantity of scheduled non-stop and one-stop air transport services. It used a connection builder to identify feasible one-stop routings assuming a set of connection rules (such as codeshare or alliance requirements and minimum layover times). The quality of indirect connections is modelled based on frequency, detours, and layover time. The disutility associated with detours and layover times for indirect connections is valued by comparing total travel time of an indirect flight with a (hypothetical) direct flight (aspatial concept) and by leveraging data on observed passenger behaviour. Furthermore, the GCI considers destination quality through quantifying wealth-adjusted population of destination airports in combination with a distance-decay model. For applications outside analyses of economic impacts, different destination weights could be used (for example, leisure destinations to capture tourism).

4.3 Connectivity and volume measures

Since only a few studies have considered connectivity, the implicit assumption could be made that airport volume measures are a sufficient proxy to the concept of connectivity. Burghouwt and Redondi (2013) provide (weak) empirical evidence that this is not the case. This sub-section provides further support that size-based measures cannot adequately measure connectivity. For this purpose, we compare airport-level data on the Global Connectivity Index (GCI, Allroggen et al., 2015) with departure statistics obtained from OAG (2019) for the world's 3,433 largest global airports in 2012[8].

To assess the strength of traffic measures as a proxy for air connectivity, Burghouwt and Redondi (2013) rely on a comparison of the airport rank distribution for volume and connectivity measures. Figure 3 reproduces the analysis for our dataset, with the addition that we divide the number of departing flights into direct connections to a (mega)hub as defined by OAG (OAG, 2017) and other connections. We find that the connectivity distribution lies above the non-hub departure distribution and coincides with the hub departure distribution. This observation implies that connectivity decreases less than the number of departures would suggest since airports can gain indirect connections through hub airports, which adds significantly to the connectivity of smaller airports.

At first glance, Figure 4 appears to indicate that the number of departures approximates connectivity reasonably well through a quadratic model (R^2 = 0.82, correlation coefficient = 0.90). Similar observations were made by Burghouwt and Redondi (2013), who reported correlation coefficients between the number of flights and different connectivity measures in the range of 0.93–0.98.

[8] This is the most recent year for which GCI data is available.

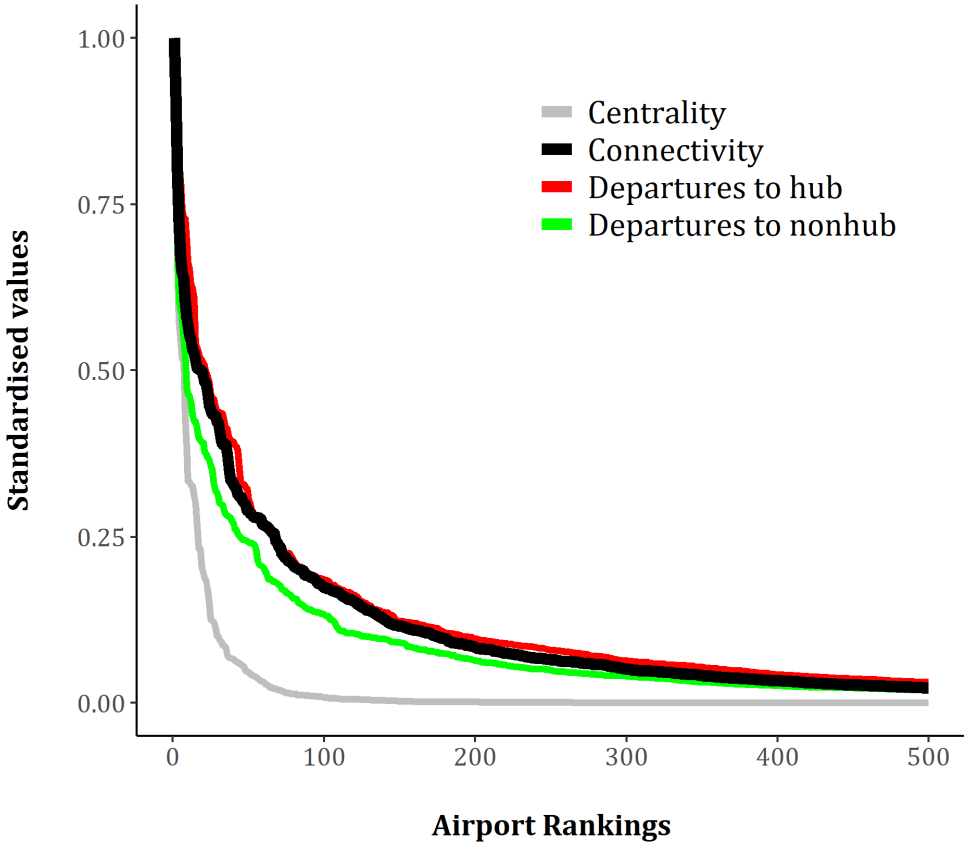


Figure 3 Distribution comparison of departures, centrality and connectivity standardised to one, according to the rank of the airport.

However, a high correlation in the sample masks some complex associations between the variables within (disjoint) subgroups. Figure 5 plots the correlation coefficient between departing flights and total GCI scores based on quantiles (defined through departure numbers). Generally, the correlation coefficient increases as we add increasingly larger airports to the sample. At the median (0.5 quantile), the coefficient equals 0.35, while it is 0.90 for the full data set. At the same time, the correlation coefficient within each of the first nine deciles is smaller than 0.25 and jumps to almost the population level for the last decile.

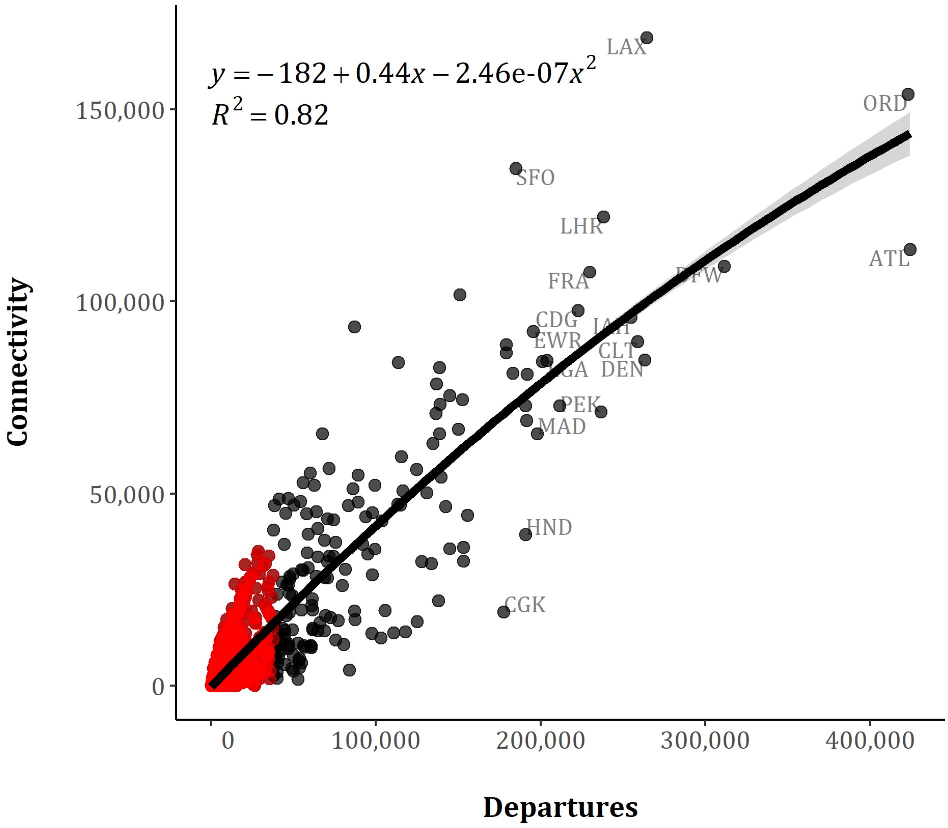


Figure 4 Scatter plots of connectivity and departures (second-order polynomial in black). Red dots represent the data below the 95 per cent quantile based on departures.

These results suggest that outlier effects for large airports drive the general association between traffic volume measures and the GCI (Figure 4). For the year-2012 dataset, 16 per cent of data points are mild outliers (> Q3 + 1.5*IQR) for connectivity, while 13 per cent can be considered extreme outliers (> Q3 + 3*IQR). Since the correlation coefficient represents an averaged trend, reinforced by outlying values, it may not represent a genuine fit for all data points.

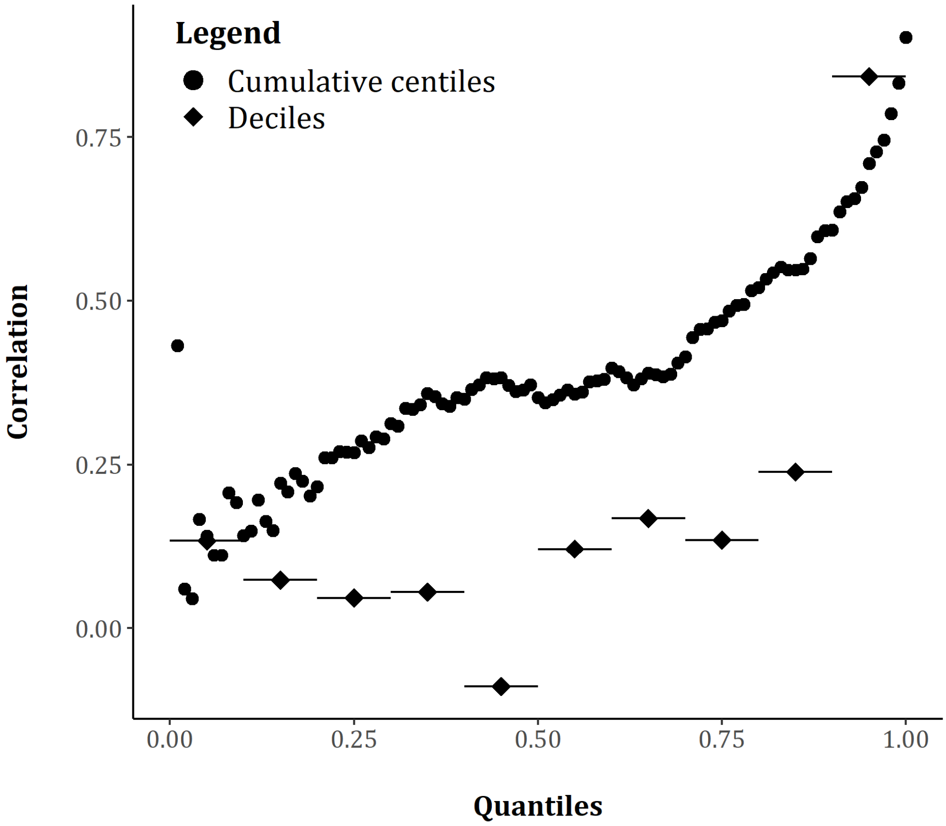
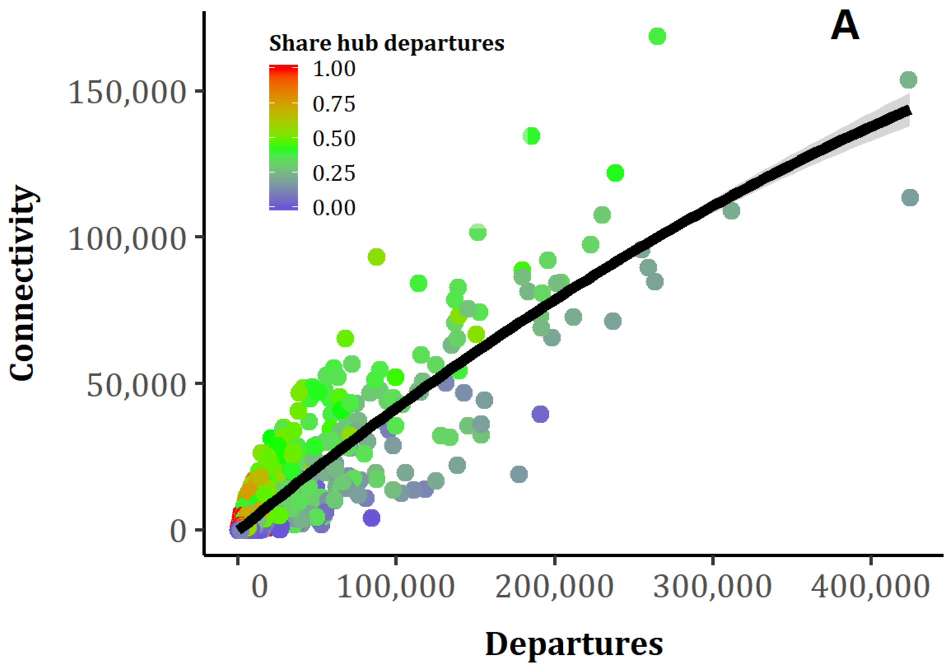


Figure 5 Scatter plot of the correlation coefficient between connectivity and departures for two quantile distributions based on departures.

Furthermore, Figure 6 suggests that there are differences in connectivity between airports with similar traffic levels. These differences arise because higher levels of connectivity are not necessarily the result of increasing departure numbers but rather the onward connectivity through multi-step connections, which are facilitated by flight connections to hub airports. This onward connectivity is especially important for some small airports. To outline this impact, we calculate the share of departures (that is, the relative number of non-stop flights departing) going to a (mega)hub as defined by OAG (OAG, 2017). Figure 6 shows a scatter plot of the number of departures versus connectivity scores, with each airport's data point being coloured according to the share of flights to a megahub. From this analysis, two trends can be identified, especially for smaller airports (Figure 6b): (i) airports with a high share of departures to hubs exhibit higher-than-expected connectivity for a given number of departures; and (ii) airports with a low share of departures to hubs exhibit lower-than-expected connectivity. A regression analysis of connectivity on the number of departures to megahubs and non-megahubs shows the connectivity coefficient of flights into hubs to be more than ten times larger than for other flights (Table 1).



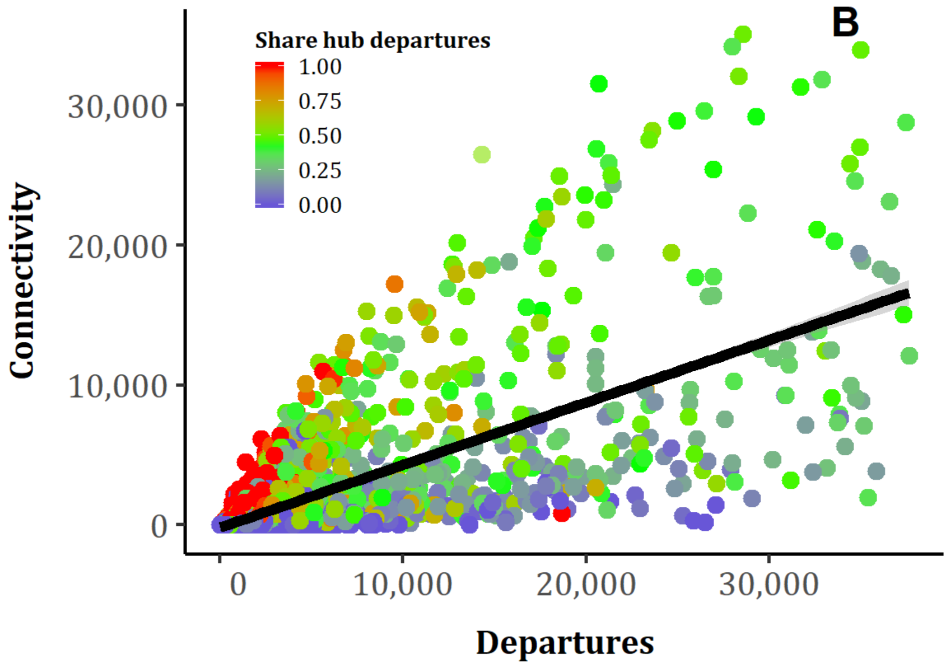


Figure 6 Scatter plots of connectivity and departures (second-order polynomial in black) for all data (panel a) and the data below the 95 per cent quantile (panel b) based on departures. Hub share represents the relative number of non-stop flights departing to a (mega) hub, as defined by the OAG (OAG, 2017).

Table 1 Regression of connectivity on the number of departures to megahubs and non-megahubs

Intercept	−89.62
	(67.01)
Departures to megahubs	1.20***
	(0.02)
Departures to other airports	0.10***
	(0.01)
Adj. R^2	0.89
Num. obs.	3,433

Notes: ***, ** and * denote significance at the 1, 5 and 10 per cent level, respectively.

Previous analyses have shown that connections to hub airports are an essential driver of air connectivity due to airport hubs' potential to generate onward connectivity, which has important implications affecting air carrier choice for airports wanting to maximise their connectivity. Full-service network carriers have developed multi-hub-and-spoke networks, while low-cost carriers have been oriented more towards point-to-point networks. In the point-to-point system, both small and large airports are designed to offer direct flights, while in the hub-and-spoke system, large airports act as connecting node airports (Alderighi et al., 2007). As a result, connections to hubs bring more onward connectivity than connections to non-hubs. This effect is likely to be larger (i) for smaller airports that have fewer connections, so the capacity of each direct flight to generate onward connectivity matters more, and (ii) in long-haul markets where intercontinental destinations are often reached by indirect connections.

5 Conclusion

In this paper, we reviewed the potential impact pathways of aviation's wider economic benefits and analysed how existing empirical studies consider these pathways. As a result of not fully appreciating these impact pathways, the causal relationship between aviation and the wider economy remains an open question. To guide future empirical work, we reviewed the New Economic Geography to obtain a comprehensive framework for understanding the mechanism behind and spatial distribution of the wider economic impacts of (air) transportation. Our framework is the first to outline both the potential positive and negative regional impacts of improving air transport links. These insights can inform policymakers to strategically assess the opportunities and challenges associated with improving transport systems. This paper subsequently adds a theoretical foundation to the positive and negative economic impacts of aviation reported by Campante and Yanagizawa-Drott (2018).

Our framework also provides a unified basis for assessing the wider economic benefits through different outcome lenses. The existing empirical literature has mainly focused on analysing the impacts on employment (e.g. Bilotkach, 2015; Brueckner, 2003; Percoco, 2010; Sheard, 2019), economic activity and growth (e.g. Allroggen and Malina, 2014; Campante and Yanagizawa-Drott, 2018), productivity (e.g. Cooper and Smith, 2005; IATA, 2007), and population (e.g. Blonigen and Cristea, 2015; Chi, 2012; Glaeser and Gottlieb, 2008). Most analyses have assessed one outcome metric at a time—even if multiple outcome metrics are considered—which often means that the circular causation mechanisms of economic geography cannot be captured.

Furthermore, our paper quantitatively compares the Global Connectivity Index metric for global airports to airport departures, a transport volume metric that is widely used for impact assessments. Following Burghouwt and Redondi (2013), we find that volume metrics are weak proxies for connectivity and cannot provide sufficient evidence for policymakers to analyse the quality of air transport links. The use of weak proxies can lead to biased impact assessments, especially since it can result in over- or undervaluing of air transport connections available to the economy surrounding an airport. This finding can directly inform the public debate where passenger numbers are often still seen as good proxies to measure the economic significance of airports.

While novel empirical analyses of wider economic benefits of aviation are beyond the scope of this paper, we bring forward a set of testable hypotheses regarding the wider economic impacts of transportation. As such, the paper informs future empirical analysis. More specifically, we recommend (i) the use of connectivity metrics for assessing wider economic benefits; (ii) the development of spatial metrics that can address the inherently geographical nature of the wider economic benefits, including heterogeneities in impacts; and (iii) the implementation of models that address the simultaneity of outcomes.

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Declaration of Interest statement

The authors declare that they have no competing interests.

References

Alderighi, M., Cento, A., Nijkamp, P., and Rietveld, P. 2007. Assessment of new hub-and-spoke and point-to-point airline network configurations, *Transport Reviews*, vol. 27, no. 5, 529–49

Alderighi, M. and Gaggero, A. A. 2017. Fly and trade: Evidence from the Italian manufacturing industry, *Economics of transportation*, vol. 9, 51–60

Allroggen, F. 2013. Foerdert ein leistungsfaehiges Verkehrssystem die wirtschaftliche Entwicklung?, *Zeitschrift Für Verkehrswissenschaft*, vol. 84, no. 3

Allroggen, F. and Malina, R. 2014. Do the regional growth effects of air transport differ among airports?, *Journal of Air Transport Management*, vol. 37, 1–4

Allroggen, F., Wittman, M. D., and Malina, R. 2015. How air transport connects the world–A new metric of air connectivity and its evolution between 1990 and 2012, *Transportation Research Part E: Logistics and Transportation Review*, vol. 80, 184–201

Alstadt, B., Weisbrod, G., and Cutler, D. 2012. Relationship of transportation access and connectivity to local economic outcomes: statistical analysis, *Transportation Research Record: Journal of the Transportation Research Board*, no. 2297, 154–62

Anderson, J. E. and Van Wincoop, E. 2004. Trade costs, *Journal of Economic literature*, vol. 42, no. 3, 691–751

Arbia, G. 1989. Spatial data configuration in statistical analysis of regional economics and related problems. Dordrecht, the Netherlands: Kluwer., Advance Access published 1989

Aschauer, D. A. 1989. Is public expenditure productive?, *Journal of Monetary Economics*, vol. 23, no. 2, 177–200

ATAG. 2014. *Aviation: Benefits beyond borders*, Geneva, Switzerland

Baker, D., Merkert, R., and Kamruzzaman, M. 2015. Regional aviation and economic growth: cointegration and causality analysis in Australia, *Journal of Transport Geography*, vol. 43, 140–50

Baldwin, R. E. 2003. *Economic Geography and Public Policy*, Princeton University Press

Baltaci, N., Sekmen, O., and Akbulut, G. 2015. The relationship between air transport and economic growth in turkey: Cross-regional panel data analysis approach, *Journal of Economics and Behavioral Studies*, vol. 7, no. 1, 89

Bannò, M. and Redondi, R. 2014. Air connectivity and foreign direct investments: economic effects of the introduction of new routes, *European Transport Research Review*, vol. 6, no. 4, 355–63

Behar, A. and Venables, A. J. 2011. Transport costs and international trade, pp. 97–115, in De Palma, A., Lindsey, R., Quinet, E., and Vickerman, R. (eds.), *A handbook of transport economics*, Edward Elgar Publishing

Behrens, K., Brown, W. M., and Bougna, T. 2016. *The world is not yet flat: Transport costs matter!*, The World Bank

Bilotkach, V. 2015. Are airports engines of economic development? A dynamic panel data approach, *Urban Studies*, vol. 52, no. 9, 1577–93

Blonigen, B. A. and Cristea, A. D. 2015. Air service and urban growth: Evidence from a quasi-natural policy experiment, *Journal of Urban Economics*, vol. 86, 128–46

Bootsma, P. D. 1997. *Airline Flight Schedule Development-Analysis and design tools for European hinterland hubs*, Utrecht., Elinkwijk B.V.

Boschma, R. 2005. Proximity and innovation: a critical assessment, *Regional Studies*, vol. 39, no. 1, 61–74

Boschma, R. and Frenken, K. 2010. The spatial evolution of innovation networks. A proximity perspective, pp. 120–35, in Boschma, R. and Martin, R. (eds.), *The handbook of evolutionary economic geography*

Brueckner, J. K. 2003. Airline traffic and urban economic development, *Urban Studies*, vol. 40, no. 8, 1455–69

Brugnoli, A., Dal Bianco, A., Martini, G., and Scotti, D. 2018. The impact of air transportation on trade flows: A natural experiment on causality applied to Italy, *Transportation Research Part A: Policy and Practice*, vol. 112, 95–107

Burghouwt, G. and De Wit, J. 2005. Temporal configurations of European airline networks, *Journal of Air Transport Management*, vol. 11, no. 3, 185–98

Burghouwt, G. and Redondi, R. 2013. Connectivity in air transport networks: an assessment of models and applications, *Journal of Transport Economics and Policy (JTEP)*, vol. 47, no. 1, 35–53

Button, K., Doh, S., and Yuan, J. 2010. The role of small airports in economic development, *Journal of Airport Management*, vol. 4, no. 2, 125–36

Button, K., Lall, S., Stough, R., and Trice, M. 1999. High-technology employment and hub airports, *Journal of Air Transport Management*, vol. 5, no. 1, 53–59

Button, K. and Taylor, S. 2000. International air transportation and economic development, *Journal of Air Transport Management*, vol. 6, no. 4, 209–22

Button, K. and Yuan, J. 2013. Airfreight transport and economic development: an examination of causality, *Urban Studies*, vol. 50, no. 2, 329–40

Campante, F. and Yanagizawa-Drott, D. 2018. Long-Range Growth: Economic Development in the Global Network of Air Links, *The Quarterly Journal of Economics*, vol. 133, no. 3, 1395–1458

Cantos, P., Gumbau-Albert, M., and Maudos, J. 2005. Transport infrastructures, spillover effects and regional growth: evidence of the Spanish case, *Transport Reviews*, vol. 25, no. 1, 25–50

Chi, G. 2012. The impacts of transport accessibility on population change across rural, suburban and urban areas: a case study of Wisconsin at sub-county levels, *Urban Studies*, vol. 49, no. 12, 2711–31

Ciccone, A. 2002. Agglomeration effects in Europe, *European Economic Review*, vol. 46, no. 2, 213–27

Ciccone, A. and Hall, R. E. 1996. Productivity and the Density of Economic Activity, *The American Economic Review*, vol. 86, no. 1, 54–70

Cidell, J. 2015. The role of major infrastructure in subregional economic development: an empirical study of airports and cities, *Journal of Economic Geography*, vol. 15, no. 6, 1125–44

Cohen, J. P. and Paul, C. J. M. 2003. Airport infrastructure spillovers in a network system, *Journal of Urban Economics*, vol. 54, no. 3, 459–73

Combes, P.-P. and Gobillon, L. 2015. The empirics of agglomeration economies, pp. 247–348, in *Handbook of regional and urban economics*, Elsevier

Cooper, A. and Smith, P. 2005. *The Economic Catalytic Effects of Air Transport in Europe*, Report prepared for Eurocontrol, Oxford, Oxford Economic Forecasting

Coscia, M., Neffke, F. M., and Hausmann, R. 2020. Knowledge diffusion in the network of international business travel, *Nature Human Behaviour*, 1–10

Cristea, A. D. and Danila, L. 2017. The Role of Aviation Networks for Urban Development, Advance Access published 2017

Danesi, A. 2006. Measuring airline hub timetable co-ordination and connectivity: definition of a new index and application to a sample of European hubs, *European Transport*, vol. 34, 54–74

Davis, D. R. and Dingel, J. I. 2013. *A spatial knowledge economy*, National Bureau of Economic Research

Dobruszkes, F., Lennert, M., and Van Hamme, G. 2011. An analysis of the determinants of air traffic volume for European metropolitan areas, *Journal of Transport Geography*, vol. 19, no. 4, 755–62

Doganis, R. and Dennis, N. 1989. Lessons in Hubbing, *Airline Business*, 42–47

Duranton, G. and Puga, D. 2004. Micro-foundations of urban agglomeration economies, pp. 2063–2117, in *Handbook of regional and urban economics*, Elsevier

Eaton, B. C. and Lipsey, R. G. 1976. The introduction of space into the neoclassical model of value, in Artis, M. J. and Nobay, A. R. (eds.), *Studies in modern economic analysis*, Oxford, Basil Blackwell

Elburz, Z., Nijkamp, P., and Pels, E. 2017. Public infrastructure and regional growth: Lessons from meta-analysis, *Journal of Transport Geography*, vol. 58, 1–8

Elhorst, J. P. 2010. Applied spatial econometrics: raising the bar, *Spatial economic analysis*, vol. 5, no. 1, 9–28

Fageda, X. 2017. International Air Travel and FDI Flows: Evidence from Barcelona, *Journal of Regional Science*, vol. 57, no. 5, 858–83

Fageda, X. and Gonzalez-Aregall, M. 2017. Do all transport modes impact on industrial employment? Empirical evidence from the Spanish regions, *Transport Policy*, vol. 55, 70–78

Fedderke, J. W. and Bogetić, Ž. 2009. Infrastructure and Growth in South Africa: Direct and Indirect Productivity Impacts of 19 Infrastructure Measures, *World Development*, vol. 37, no. 9, 1522–39

Florida, R., Mellander, C., and Holgersson, T. 2015. Up in the air: the role of airports for regional economic development, *The Annals of Regional Science*, vol. 54, no. 1, 197–214

Frances, C. 2001. *The Death of Distance 2.0: How the Communications Revolution Will Change Our Lives*, New York, Texere Publishing

Fujita, M. 2007. The development of regional integration in East Asia: From the viewpoint of spatial economics, *Review of Urban & Regional Development Studies*, vol. 19, no. 1, 2–20

Fujita, M., Krugman, P. R., and Venables, A. J. 1999. *The spatial economy: cities, regions and international trade*, Wiley Online Library

Gaspar, J. and Glaeser, E. L. 1998. Information technology and the future of cities, *Journal of Urban Economics*, vol. 43, no. 1, 136–56

Geurs, K. T. and Van Wee, B. 2004. Accessibility evaluation of land-use and transport strategies: review and research directions, *Journal of Transport Geography*, vol. 12, no. 2, 127–40

Gherghina, Ş., Onofrei, M., Vintilă, G., and Armeanu, D. 2018. Empirical evidence from EU-28 countries on resilient transport infrastructure systems and sustainable economic growth, *Sustainability*, vol. 10, no. 8, 2900

Gibbons, S. and Wu, W. 2017. *Airports, market access and local economic performance: Evidence from China*

Glaeser, E. L. and Gottlieb, J. D. 2008. The economics of place-making policies, *Brookings Papers on Economic Activity*, Advance Access published 2008

Glaeser, E. L. and Kohlhase, J. E. 2004. Cities, regions and the decline of transport costs, *Papers in Regional Science*, vol. 83, no. 1, 197–228

Glaeser, E. L., Kolko, J., and Saiz, A. 2001. Consumer city, *Journal of Economic Geography*, vol. 1, no. 1, 27–50

Goetz, A. R. 1992. Air passenger transportation and growth in the US urban system, 1950–1987, *Growth and Change*, vol. 23, no. 2, 217–38

Green, R. K. 2007. Airports and economic development, *Real Estate Economics*, vol. 35, no. 1, 91–112

Hansen, W. G. 1959. How accessibility shapes land use, *Journal of the American Institute of Planners*, vol. 25, no. 2, 73–76

Harris, C. D. 1954. The, Market as a Factor in the Localization of Industry in the United States, *Annals of the Association of American Geographers*, vol. 44, no. 4, 315–48

Head, K. and Mayer, T. 2004. The empirics of agglomeration and trade, pp. 2609–69, in *Handbook of regional and urban economics*, Elsevier

Helpman, E. 1998. The size of regions, *Topics in Public Economics: Theoretical and Applied Analysis*, 33–54

Henderson, J. V., Squires, T., Storeygard, A., and Weil, D. 2017. The global distribution of economic activity: Nature, history, and the role of trade, *The Quarterly Journal of Economics*, vol. 133, no. 1, 357–406

Hong, J., Chu, Z., and Wang, Q. 2011. Transport infrastructure and regional economic growth: evidence from China, *Transportation*, vol. 38, no. 5, 737–52

Hu, Y., Xiao, J., Deng, Y., Xiao, Y., and Wang, S. 2015. Domestic air passenger traffic and economic growth in China: Evidence from heterogeneous panel models, *Journal of Air Transport Management*, vol. 42, 95–100

Hummels, D. 2007. Transportation costs and international trade in the second era of globalization, *The Journal of Economic Perspectives*, vol. 21, no. 3, 131–54

IATA. 2007. *Aviation Economic Benefits*, Economics Briefing 8, IATA

Irwin, M. D. and Kasarda, J. D. 1991. Air passenger linkages and employment growth in US metropolitan areas, *American Sociological Review*, 524–37

Ivy, R. L., Fik, T. J., and Malecki, E. J. 1995. Changes in air service connectivity and employment, *Environment and Planning A*, vol. 27, no. 2, 165–79

Jenkins, J. J. 2011. *The evolution of passenger accessibility in the US airline industry, 1980-2010*, Massachusetts Institute of Technology

Knoben, J. and Oerlemans, L. A. 2006. Proximity and inter-organizational collaboration: A literature review, *International Journal of Management Reviews*, vol. 8, no. 2, 71–89

Krugman, P. 1980. Scale economies, product differentiation, and the pattern of trade, *The American Economic Review*, vol. 70, no. 5, 950–59

Krugman, P. 1991. Increasing returns and economic geography, *Journal of Political Economy*, vol. 99, no. 3, 483–99

Krugman, P. 1993. On the number and location of cities, *European Economic Review*, vol. 37, nos. 2–3, 293–98

Krugman, P. 1996. Urban concentration: the role of increasing returns and transport costs, *International Regional Science Review*, vol. 19, nos. 1–2, 5–30

Krugman, P. and Venables, A. J. 1995. Globalization and the Inequality of Nations, *The Quarterly Journal of Economics*, vol. 110, no. 4, 857–80

Krugman, P. and Venables, A. J. 1996. Integration, specialization, and adjustment, *European Economic Review*, vol. 40, nos. 3–5, 959–67

Lakew, P. A. and Bilotkach, V. 2018. Airport delays and metropolitan employment, *Journal of Regional Science*, vol. 58, no. 2, 424–50

Lakshmanan, T. R. 2011. The broader economic consequences of transport infrastructure investments, *Journal of Transport Geography*, vol. 19, no. 1, 1–12

Lee, S. Y., Yoo, K. E., and Park, Y. 2014. A continuous connectivity model for evaluation of hub-and-spoke operations, *Transportmetrica A: Transport Science*, vol. 10, no. 10, 894–916

LeFors, M. D. 2015. *Essays on Transportation Innovations and Local Development*, University of California, Irvine

Lenaerts, B., Allroggen, F., and Malina, R. 2020. Measuring the quality of air transport networks – A topology of connectivity and accessibility metrics, in *Handbook on Air Transport and Regional Development (accepted)*

Letaifa, S. B. and Rabeau, Y. 2013. Too close to collaborate? How geographic proximity could impede entrepreneurship and innovation, *Journal of Business Research*, vol. 66, no. 10, 2071–78

Li, Z., Hensher, D. A., and Rose, J. M. 2010. Willingness to pay for travel time reliability in passenger transport: A review and some new empirical evidence, *Transportation research part E: logistics and transportation review*, vol. 46, no. 3, 384–403

Lieshout, R. 2012. Measuring the size of an airport's catchment area, *Journal of Transport Geography*, vol. 25, 27–34

Marazzo, M., Scherre, R., and Fernandes, E. 2010. Air transport demand and economic growth in Brazil: A time series analysis, *Transportation Research Part E: Logistics and Transportation Review*, vol. 46, no. 2, 261–69

Marshall, A. 1890. *Principles of economics*, London, Macmillan

McGraw, M. J. 2015. *Perhaps the Sky's the Limit? Airports and Employment in Local Economies*, Working Paper

McGraw, M. J. 2017. *Does Airport Size Matter? Hub Airports and Local Economic Outcomes*

Mukkala, K. and Tervo, H. 2013. Air transportation and regional growth: which way does the causality run?, *Environment and Planning A*, vol. 45, no. 6, 1508–20

Neal, Z. 2010. Refining the air traffic approach to city networks, *Urban Studies*, vol. 47, no. 10, 2195–2215

Neal, Z. 2012. Creative employment and jet set cities: disentangling causal effects, *Urban Studies*, vol. 49, no. 12, 2693–2709

Nonaka, I. and Takeuchi, H. 1995. *The knowledge-creating company: How Japanese companies create the dynamics of innovation*, Oxford university press

OAG. 2017. *Megahubs International Index – The World's Most Internationally Connected Airports*, OAG

OAG. 2019. <https://www.oag.com>

O'Brien, R. 1992. *The end of geography: global financial integration*, London, Pinter

OECD. 2008. Economic Geography and GDP Per Capita, p. 154, in *Economic Policy Reforms: Going for Growth*, Paris, OECD

Percoco, M. 2010. Airport activity and local development: evidence from Italy, *Urban Studies*, vol. 47, no. 11, 2427–43

Ploeckl, F. 2012. Endowments and market access; the size of towns in historical perspective: Saxony, 1550–1834, *Regional Science and Urban Economics*, vol. 42, no. 4, 607–18

Profillidis, V. and Botzoris, G. 2015. Air passenger transport and economic activity, *Journal of Air Transport Management*, vol. 49, 23–27

Redding, S. and Schott, P. K. 2003. Distance, skill deepening and development: will peripheral countries ever get rich?, *Journal of Development Economics*, vol. 72, no. 2, 515–41

Redding, S. J. and Turner, M. A. 2015. Transportation costs and the spatial organization of economic activity, pp. 1339–98, in *Handbook of regional and urban economics*, Elsevier

Rietveld, P. and Brons, M. 2001. Quality of hub-and-spoke networks; the effects of timetable co-ordination on waiting time and rescheduling time, *Journal of Air Transport Management*, vol. 7, no. 4, 241–49

Rosenthal, S. S. and Strange, W. C. 2004. Evidence on the nature and sources of agglomeration economies, pp. 2119–71, in *Handbook of regional and urban economics*, Elsevier

Sellner, R. and Nagl, P. 2010. Air accessibility and growth–The economic effects of a capacity expansion at Vienna International Airport, *Journal of Air Transport Management*, vol. 16, no. 6, 325–29

Seredyński, A., Rothlauf, F., and Grosche, T. 2014. An airline connection builder using maximum connection lag with greedy parameter selection, *Journal of Air Transport Management*, vol. 36, 120–28

Sheard, N. 2014. Airports and urban sectoral employment, *Journal of Urban Economics*, vol. 80, 133–52

Sheard, N. 2019. Airport size and urban growth, *Economica*, vol. 86, no. 342, 300–335

Sinai, T. and Waldfogel, J. 2004. Geography and the Internet: Is the Internet a Substitute or a Complement for Cities?, *Journal of Urban Economics*, vol. 56, no. 1, 1–24

Tam, R. and Hansman, R. J. 2002. *Impact of air transportation on regional economic and social connectivity in the United States*

Tittle, D., McCarthy, P., and Xiao, Y. 2013. Airport runway capacity and economic development: a panel data analysis of metropolitan statistical areas, *Economic Development Quarterly*, vol. 27, no. 3, 230–39

Tveter, E. 2017. The effect of airports on regional development: Evidence from the construction of regional airports in Norway, *Research in Transportation Economics*, vol. 63, 50–58

Van De Vijver, E., Derudder, B., and Witlox, F. 2014. Exploring causality in trade and air passenger travel relationships: the case of Asia-Pacific, 1980–2010, *Journal of Transport Geography*, vol. 34, 142–50

Van de Vijver, E., Derudder, B., and Witlox, F. 2016. Air passenger transport and regional development: Cause and effect in Europe, *Promet-Traffic & Transportation*, vol. 28, no. 2, 143–54

Veldhuis, J. 1997. The competitive position of airline networks, *Journal of Air Transport Management*, vol. 3, no. 4, 181–88

Venables, A. J. 1996. Equilibrium locations of vertically linked industries, *International Economic Review*, 341–59

Wittman, M. D. and Swelbar, W. S. 2013. *Modeling changes in connectivity at US airports: A small community perspective*

World Bank. 2008. *World Development Report 2009: Reshaping Economic Geography*, Washington, DC, The World Bank

Yamaguchi, K. 2007. Inter-regional air transport accessibility and macro-economic performance in Japan, *Transportation Research Part E: Logistics and Transportation Review*, vol. 43, no. 3, 247–58

Zak, D. and Getzner, M. 2014. Economic effects of airports in Central Europe: A critical review of empirical studies and their methodological assumptions, *Advances in Economics and Business*, vol. 2, no. 2, 100–111

Zhang, Y., Zhang, A., Zhu, Z., and Wang, K. 2017. Connectivity at Chinese airports: The evolution and drivers, *Transportation Research Part A: Policy and Practice*, vol. 103, 490–508

Appendix

Table A.1 Empirical studies on the wider economic impact of aviation

Study	Spatial unit	Time dimension	Impact variable	Outcome variable	Method	Result
Irwin and Kasarda (1991)	104 US metropolitan areas	1950–1980	Level of and change in Bonacich centrality	Employment (by industry)	FIML	+
Goetz (1992)	50 largest US air passenger metropolitan areas	1950–1987	Total passengers PC (total passengers per total employed)	Population (employment) growth	OLS	+
Ivy et al. (1995)	50 largest metropolitan areas	1978–1988	Average yearly rate of change in gross vertex connectivity	Average yearly rate of change in administrative and auxiliary employment	3SLS	+
Button et al. (1999)	321US metropolitan areas	1994	Hub dummy	High-technology employment	OLS	+
Button and Taylor (2000)	41 US metropolitan areas	1994/1996	Total European passengers, the number of European airports served, and departing passengers	Employment	OLS	na (positive coefficients)
Brueckner (2003)	91 US metropolitan areas	1996	Departing passengers	Employment (total and by industry)	OLS and 2SLS	+
Cohen and Paul (2003)	48 continental United States	1982–1996	Airport capital	Manufacturing cost	OLS	-
Cantos et al. (2005)	Spanish regions	1965–1995	Airport capital	Total factor productivity	Two-way FE with instrumentation	0 / +

Cooper and Smith (2005)	24 EU countries	1994–2003	Metric tonne equivalents of total passengers and volume of freight over origin GDP	Total factor productivity and investment	OLS	+
Green (2007)	83 US metropolitan areas	1990–2000	Departing passengers PC, passenger originations PC, freight PC and hub dummy	Population and employment growth	OLS and 2SLS	freight: 0 rest: +
IATA (2007)	48 countries	1996–2005	Weighted number of seats per flight over origin GDP	Labour productivity (GDP per hour worked)	FE	0
Yamaguchi (2007)	47 Japanese prefectures	1995–2000	Accessibility index weighted by relative economic level of origin and destination	Growth in GDP per employee	3SLS	+
Glaeser and Gottlieb (2008)	US metropolitan areas	1990–2000	Airport dummy (top 50)	Population growth and income PC growth	OLS	+
Fedderke and Bogetić (2009)	22 South African manufacturing sectors	1970–1993	Total passengers	Output per employee and total factor productivity	FE-VECM with instrumentation	+
Button et al. (2010)	Counties surrounding air carrier airports in Virginia	1990–2007	Total passengers	Real personal income PC	FE and RE	RE:0 FE:+
Marazzo et al. (2010)	Brazilian domestic market	1966–2006	Onboard passenger-kilometres	GDP	VAR and VECM	+
Percoco (2010)	103 Italian provinces	2002	Total passengers and total flights	Employment (total and by industry)	2SLS (PSM) and SLX-2SLS (PSM)	services: +

Sellner and Nagl (2010)	EU-15 countries	1993–2006	Total passengers PC	GDP PC and investment rate	SUR	GDP PC:+
Hong et al. (2011)	31 Chinese provinces	1998–2007	Index of area of airport lounge, length and pavement condition of runways, and density of airport	Real GDP PC growth	POLS, RE, FE and FE-2SLS	POLS:+ RE and FE:0
Alstadt et al. (2012)	3141 US counties	Na	Drive time to and operations at closest airport	Employment, output and exports	2SLS	+
Chi (2012)	Sub-counties in Wisconsin	1980–1990	Index of distance to closest airport and departing passengers	Population growth	OLS and SR	+
Neal (2012)	128 US metropolitan areas	2001–2008	Lagged total passengers	Creative employment	OLS	+
Button and Yuan (2013)	32 US metropolitan areas	1990–2009	Cargo volume	Employment and personal income (total and PC)	VAR	+
Mukkala and Tervo (2013)	86 NUTS 2 or 3 regions from 13 European countries	1991–2010	Average travel time using the best combination of air, rail, and road weighted by relative destination GDP, and total passengers	GDP and employment	Heterogeneous panel-VAR	+
Tittle et al. (2013)	35 US metropolitan areas	2002–2007	Number of runways, maximum runway length, average flight delay, large hub dummy	Real gross metropolitan product	Two-way FE	+

Allroggen and Malina (2014)	11 German airports regions	1997–2006	Airport capital and total flights	Output	FD-LIML	+
Bannò and Redondi (2014)	Italian firms	2001–2010	Introduction of a new route	FDI exchange between newly connected regions	Allocation of FDIs to new routes	+
Sheard (2014)	290 US metropolitan areas	2007	Departing flights	Employment by sector and total employment growth	Regional FE combined with OLS and 2SLS	employment tradables: + employment growth: 0
Van De Vijver et al. (2014)	Nine countries and 33 country pairs	1980–2010	Seats	Trade	Heterogeneous panel-VAR	between more and less developed economies: +
Cidell (2015)	25 largest airports	2007	Airport location	employment	Clustering and concentration analyses	0 / +
Baker et al. (2015)	88 Australian airports regions	1985–2013	Total passengers	Aggregate real taxable income	VECM	+
Baltaci et al. (2015)	26 Turkish NUTS 2 regions	2004–2011	Summed departing flights and total passengers PC	GVA PC	POLS, FE and POLS-2SLS	+
Bilotkach (2015)	each US metropolitan area housing a primary commercial passenger airport	1993–2009	Total passengers, total flights and number of unique destinations served by non-stop flights	Average wage, number of establishments, employment,	FE-2SLS and dynamic FE-GMM	+
Blonigen and Cristea (2015)	263 US metropolitan areas	1969, 1977 and 1991	Growth in departing passengers	Growth in population, employment and per-capita income	FE-DID and FE-2SLS	+

Hu et al. (2015)	29 Chinese provinces	2006–2012	Total passengers	GDP	FMOLS and panel VECM (GMM)	+
Florida et al. (2015)	US metropolitan areas	2010	Total passengers PC, total cargo PC, airport dummy and a common factor of total passengers PC, total flights PC and total cargo PC	Gross regional product PC	OLS and PSM	+
LeFors (2015)	±200 US metropolitan areas	2000 and 2007	Accessibility index of travel cost weighted by destination population	Growth in tradable services employment, population, total employment, and gross metropolitan product	OLS and 2SLS	tradable services employment:+ rest: 0 (positive coefficients)
	US counties	1979–1987 and 1990–2000	Essential Air Service programme	Employment	OLS and PSM	+
McGraw (2015)	524 US metropolitan areas	1950–2010	Airport dummy	Population and employment (total and by industry)	Regional FE combined with OLS, 2SLS and PSM	+
Van de Vijver et al. (2016)	112 NUTS 2 regions	2002–2011	Total passengers	Employment in total, manufacturing and services	Heterogeneous panel-VAR	+
Alderighi and Gaggero (2017)	20 Italian regions	1998–2010	Total flights	Manufacturing exports	FE-GMM	+
Elburz et al. (2017)	42 studies (meta-analysis)	1995–2014	Measures of airport infrastructure	Probability of finding negative, positive, and insignificant impacts on regional growth	Meta-analysis	-

Fageda and Gonzalez-Aregall (2017)	47 Spanish provinces (NUTS 3 regions)	1995–2008	Total amount of freight moved in the airports	Industrial employment	Two-way FE-SDM-LIML	0
Fageda (2017)	Spanish region of Catalonia	2005–2015	Departing flights	FDI	Regional FE combined with either OLS, 2SLS, PPML or GLM (gamma or negatively binomially distributed)	+
Gibbons and Wu (2017)	Chinese counties	2001–2005 and 2005–2009	Accessibility index of travel time weighted by destination population and adjusted for land travel time to the closest airport	Firm gross output	Industry and time FE combined with either subsampling or instrumentation	+
McGraw (2017)	48 airport commuting zones	1978–2012	Hub dummy	Employment and number of establishments (total and per industry); and payroll, wage/salary, and personal income (total and PC)	Two-way FE	overall: 0 per decade: +/-
Cristea and Danila (2017)	147 US metropolitan areas	1984–2001	Frequency- and destination-weighted degreeness	Population growth, employment, income and new firm entry	Time FE-OLS and time FE -LIML	population growth, employment, and new firm entry: + income: 0
Tveter (2017)	9 Norwegian municipalities	1970 and 1980	Construction of new regional airports	Population and employment growth	DID	0 (positive coefficients)

Brugnoli et al. (2018)	Italian region of Lombardy	2004–2014	Seats	Total, agriculture, industrial and manufacturing trade	RE, PPML and PPML-FE	+
Gherghina et al. (2018)	EU-28 Member States	1990–2016	Total passengers, cargo volume and airport investment	GDP PC	FE	passengers: + cargo: 0/+ investment: 0/+
Lakew and Bilotkach (2018)	175 US metropolitan areas	2004–2012	Departure (arrival) delays and departing (arriving) passengers	Employment (by industry)	FE-2SLS	services: 0/+ goods: +
Campante and Yanagizawa-Drott (2018)	819 cities with major international airports	1990/1992 and 2010	Average eigenvector centrality and centrality-weighted share of cities below 6000 miles	Growth in light density at night	RD and FE-2SLS, both spatially subsampled	+
Sheard (2019)	182 US metropolitan areas	1991–2014	Growth in departing passengers, departing flights (unweighted and weighted by population), and seats on departing flights	Employment and GDP	Two-way FE with and without 2SLS	+

Note: - significant negative effects. + significantly positive effects. 0 no significant effects. 2SLS/3SLS, two- and-three stage least squares, respectively. 'Arriving passengers', the number of inbound passengers (landings). 'Departing passengers', the number of outbound passengers (boardings or enplanements). DID, difference-in-difference. FD, first-differenced. FE, group or spatial fixed effects (unless specified otherwise). FIML/LIML, full information and limited information maximum likelihood, respectively. FMOLS, fully modified OLS. GMM, generalised method of moments. 'Passenger originations', passengers directly delivered to the destination. PC, per capita. POLS, pooled ordinary least squares. PPML, Poisson pseudo-maximum likelihood. PSM, propensity score matching. RD, regression discontinuity. RE, random effects. SDM, spatial Durbin model. SLX, spatially lagged X model. SR, spatial regime. SUR, seemingly unrelated regression. 'Total flights', the number of aircraft movements. 'Total passengers', both departing and arriving passengers. VAR, vector autoregressive model. VECM, vector error correction model.