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ASSESSING INEQUALITIES IN ACCESS TO AIR TRANSPORT SERVICES ACROSS EUROPE (EEA + UK + SWITZERLAND)

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ABSTRACT:
Air transport networks tend to develop in accordance with underlying economic activity and links. This relationship in Europe has not developed entirely evenly or consistently, however, with some regional population centres having comparatively low levels of access to air transport services and global markets. This study focusses on air transport access inequality across 1,388 regions in Europe using the 20:20 ratio, a commonly used indicator in macroeconomic income inequality studies. The highest levels of inequality were found in some Spanish, and Finnish regions.

1. Introduction

Air transport is an example of a network industry, with the supply for aviation services closely matching the spatial distribution of demand. It is widely recognised that demand for transport services is derived from demand for other activities, products and services (Cole, 2005; Vasigh et al. 2018 *inter alia*). Therefore, historically the creation of air transport infrastructure and services has gravitated around agglomerated population centres, which in themselves have become increasingly inter-connected in the areas of production and consumption, trade, commerce, healthcare, education and leisure. On the flip side, however, areas that do not generate or attract sufficient transport demand can suffer from the opposite effect and become disconnected from many of those opportunities. Inequalities in air transport connectivity can be a major obstacle to equity and regional cohesion and can hinder economic and social development. Over the last fifty years, air transport has facilitated and expedited levels of connectedness between agglomerated centres that would otherwise be too distant and/or too impractical to bridge. Nevertheless, without the underpinning economic and social activity driving global output and consumption more generally, the need for longer distance transport links also fades.
Due to indivisibilities of supply and *infrastructure,* and to the long planning and construction timescales associated with transportation not to mention the conflicting investment priorities of government, developments in transport infrastructure and services have not been uniform or entirely consistent with developments and growth in population centres. Moreover, owing to the multiplier effects associated with economic and social activity in major urban centres, there has been a tendency over time for the quality and availability of transport services in different parts of a country or

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region to diverge. Despite being on a wider, global scale, the development of air transport infrastructure and services have followed a similar pattern, with major aviation hubs acting as magnets for yet further growth and investment. Aviation suppliers have persistently sought scale related efficiencies that would otherwise be diluted if infrastructure and services were spread out to more accurately reflect the underlying distribution of populations and wider economic activity in a country or region.

An aspect that is often neglected is the extent to which inequalities in air transport access have developed and widened over time both within and between states at the sub-regional level. When dispersion effects have been examined, it has been primarily through the lens of network and spatial assessments. These assessments (detailed in Section 2) are useful in their own right but do not allow for the measurement and monitoring of overall disparities in levels of air transport connectivity and access by specific sub-region of residence. It is also currently difficult to gauge for any given population area, whether air transport network disparities are a simple reflection of underlying disparity in economic and social activity or not. In this study, inequality measures that are typically used within the macroeconomics domain have been applied to air transport connectivity indicators in order to help stakeholders more easily determine levels of air access inequality for any given state, region or sub-region. Those indicators are then complemented by population data using the highest level of disaggregation possible. The availability of data for the European Union and the European Economic Area allowed the application of air access inequality measures to over 1,380 sub-regions across the European continent (at NUTS3 level). The fact that as many as 71% of European airports with less than 1 million passengers per annum were already loss making (ACI Europe, 2021) signalled a need for a more in-depth phase to the research, that allows for more context and specific circumstances to be drawn out on a sub-sample of regions that are deemed to be the most cut-off and unequal in comparison to other country regions or indeed between countries by including further indicators of Vulnerability and Dependence (V/D). The baseline year is 2019 with the impact of the pandemic through 2020 being used on the shortlisted regions to see the extent to which the absolute and relative (inequality) level of access changed as a result of Covid related travel restrictions and accompanying economic downturns.

The rest of the paper is set out as follows: Section 2 reviews the evidence and approaches to date on examining disparity of air transport connectivity and access between regions, Section 3 lays out the chosen methodology, alternative assumptions that were deselected and also the chosen data approach, Sections 4, 5 and 6 contain the results, analysis and findings from the whole population of European sub-regions and also the in-depth vulnerability and dependence analysis on the shortlisted group of sub-regions, Section 7 draws policy and stakeholder implications from the findings and concludes.

2. Evidence of disparities in access to air transport services

There have been several approaches to measuring the distribution of access to transport services, in most cases though an ad-hoc methodology tailored to a specific case study, though with regards to air transport, there has been a dearth of distributional analysis at a sub-regional level and more generally a an absence of looking at distributional analysis from an inequality perspective.

Through an examination of access to transport services more generally, Clifton and Lucas (2004) found evidence in the US and UK of distributional inequalities in transport access but that inequalities in themselves do not necessarily justify the need for social policy intervention. It may be justified,

"An often-neglected aspect is the extent to which inequalities in air transport access have developed and widened over time"

however, where the social welfare of residents is undermined by a lack of access to key activities, namely employment, education and training, healthcare, and social leisure and cultural activities. This text did not consider longer distance or air transport access inequality specifically.

Research carried out by Jin et al. (2004) covering a long time period between 1980 and 1998 in domestic Chinese markets found that the air transport network spread out into medium and smaller cities with the dominance of hub airports reducing. It was also noted, however, that the centroid of passenger volumes moved towards the southeast of the country, which was consistent with the expansion of

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economic growth in southeast coastal regions, to the point where the Eastern regions had a much higher share of passengers than its share of population and GDP.

There is a wealth of evidence of regional income disparities but few that focus on regional or sub-regional level transport and urban network inequalities specifically. Liu et al. (2015) found that transport access was both the driver and outcome of rising income inequality in southeast Asia. Centrality (degree, closeness and betweeness) is used as the key measure and is combined with a Gini coefficient to determine level of inequality across 47 different southeast Asian cities connected by road, rail and air. The strengths of this study are in its multi-modal focus and combined connectivity measure, whilst the drawback is that for air connections, it employed number of weekly flights (frequency) using SkyScanner data. This approach ignores passenger flows on routes, and multi-airport catchment area effects. It also did not consider smaller regions with all 47 cities in the sample being above 0.5 million inhabitants (unless a capital with a population of less than 0.5 million).

There is already a substantial body of work focussing on regional air transport networks. Research by Martini et al. (2020), for example, looked at regional air connectivity across Europe and concluded that there were improvements between 2008 and 2018 for regions at NUTS2 regional level in terms of connectivity, number of seats available and number of LCC seats available. By 2018 it was also found that connectivity in core regions was about 30% better than remote regions. The relevance of regional populations were not specifically measured, however, and levels of government support (e.g. PSOs) particularly relevant for remoter regions were not considered. There were also no indicators of the vulnerability of these regions to sudden changes in air service supply or the dependence of such regions on air transport for long distance transport mobility and underlying economic activity. Further, the study only considered the intra-EU network rather than all connections from a particular European airport or region.

In light of the perceived fragility of air carriers in the Central and Eastern European (CESE) areas of Europe culminating in the collapse of Hungarian national carrier Malev, PwC was commissioned by the European Union Directorate-General for Mobility and Transport (PwC, 2014) to conduct a study on air transport connectivity developments in the CESE countries between 2003 and 2013, highlighting any gaps in connectivity arising from airline failures and their socio-economic impacts. Overall, the study found that there was a large increase in air traffic during the 2003-2013 period, with average connectivity and number of routes also growing significantly though tailing off slightly towards 2013 due to a number of airline bankruptcies. It was further noted that new LCC services that replaced previous FSA services helped to mitigate against some of the service gaps created by failures but at the time of writing not enough to see a continued growth in overall connectivity and routes into 2013, with gaps to longer distance points outside the EU15 area being of particular note. At the thinner end of the market (e.g. on intra-CESE local and feeder routes), the study also found some evidence of neglect of direct and indirect connectivity with intercontinental hubs lying outside the region (with the exception of Warsaw) and a lack of strong FSA/hub carriers to provide connections to secondary points that are either too thin or too distant to be immediately attractive to LCCs. The scope of this study was not Europe wide, however, did not take full account of the home based expansion of LCC routes much of which took place after the study was conducted, and did not consider air access inequality at the sub-regional level.

There has also been some focus on smaller airports and in particular the issues and challenges they face in providing sustainable growth in air services and connectivity. Dziedzic et al. (2016) found that a staggering 95 of the 146 observed European airports of 1mn passengers per annum or less were reliant on one carrier for 50% or more of total traffic, clearly demonstrating the power imbalance between airlines and regional airports. The study further found that smaller airports focusing only on tourism traffic experienced more rapid downturns in air traffic and connectivity. Conversely areas/airports able to sustain year round links to major urban areas and international hubs were less likely to experience rapid alterations in traffic. A study by Kazda et al. (2017) looking at very small airports of 200,000 passengers per annum or less in Slovakia, found that the crude economic impact of the airports to their surrounding regions may not justify the taxpayer supported losses for these types of airports not able to reach a critical mass of traffic or aero and non-aero revenues to pay for regulated infrastructure

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that airports of any size must construct. There has been no particular focus in these studies on inequalities of air access between airports and by extension between sub-regions, however, which would add further important insights into the need for state or public intervention.

3. Methodology and data approach

The approach followed here combines well-known indicators that measure connectivity, dependence and vulnerability with the equality concept, which addresses the socio-economic aspects of the distributional analysis.

3.1 Air transport connectivity

The literature on connectivity focusses on measures of centrality (degree, betweenness, closeness and eigenvalue found in Veidhuis, 1997, Malighetti et al. 2008 and Burghouwt and Redondi, 2013) and measures of accessibility (i.e. network reach e.g. Shortest Path Length SPL found in Shaw, 1993, Cronrath et al. 2008, Paleari et al. 2010 and Martini et al. 2020) but, as previously stated, network connectivity studies tend not to apply inequality ratios given that the latter are most often used in the income economics domain. Given that this study's primary focus is on disparity of air transport access between regions at the sub-regional level and also within any given EEA-UK country, degree centrality (i.e. number of unique airport connections for people living in any given sub-region) has been applied as the most appropriate, comprehensible and comparable connectivity indicator on which to apply inequality measures.

3.2 Air transport access inequality

This paper applies the 20:20 ratio to measure air transport access inequality, using degree centrality as the variable to be compared. Similar to the Gini index, the 20:20 ratio is one of the United Nations Development Programme Human Development Indicators (Equality Trust, 2021). The ratio can be applied at a different percentile (e.g. 10:10 or 5:5), which may be useful where there is more evidence of disparity amongst the most and least connected regions in comparison to the middle 80% or 90% of regions.

3.3 Geographical scope and link with airports and population

A total of 1,388 NUTS3 level sub-regions in the EEA + UK were analysed in this study. Due to a lack of sub-regional level data, non-EU states in the Balkans have not been included. Any scope that this creates for underestimating levels of connectivity in neighbouring EEA states was mitigated during the in-depth vulnerability and dependence analysis (see section 3.5). The French overseas territories were also excluded from the analysis due to the distorting effect they would have on the results. NUTS3 regional access to airport gateways was measured using both 100km and 200km thresholds from the NUTS3 centroid point using Haversine great circle distance. Using the lowest sub-regional level breakdown minimised the scope for wide dispersion of populations within regions. If NUTS2 regions were used then in a number of cases actual population centres may be some considerable distance from the region's centroid point. It was concluded that the use of the 200km threshold at NUTS3 level led to a bottom 20% of sub-regions, where residents can be considered to be inconvenienced due to lengthier ground transport trips versus those that have to travel on average 100km or less in order to access nearest airports. The degree centrality of a particular sub-region was then determined by calculating the number of unique destinations at all airports within 200km of the NUTS3 region centroid point. If two airports within 200km had many overlapping direct connections, then the overall degree for that sub-region would be lower. Conversely, if a sub-region had two airports within 200km with a higher level of distinct destinations then the overall degree would be higher. Population data was then added to the analysis for each NUTS3 region and contrasted with the intermediate degree results in order to sort regions by population per unique destination (population to degree ratio). This was used as the basis to generate the initial 20:20 list at EEA-UK level. Degree centrality and the population to degree ratio were also computed by country by listing NUTS3 regions in country. Germany has the highest number of NUTS3 regions with 401 NUTS3 regions whilst due to their small size, Cyprus and Liechtenstein both have only one NUTS3 region. This allowed for a between country inequality comparisons of both the basic degree and pop:degree indicators including versus the average EEA-UK inequality level.

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3.4 Assumptions used

In order to control for the effect of atypical or inconsistent operations, only connections with 2,400 passengers (corresponding to one operation of a 200 seater aircraft per month) per year in either direction or above were included in the analysis. This equates to 412 airports in the EEA+UK area.

The dataset was run for whole years in 2010 and 2019 though the deeper analysis focussed on the most recent pre-pandemic year to create a baseline - 2019 and, for the shortlisted regions, monthly 2020 data was used through to January 2021.

It was assumed in the base algorithm that passengers do not have easier ground access journeys to non-EEA states (e.g. Estonia to Russia). In practice, there may be cases where it is more convenient for EEA based passengers to fly from a non-EU airport. This possibility is taken into account at the shortlisted sub-region stage of the analysis (during the vulnerability and dependence assessment).

It is possible within the EEA-UK area for NUTS3 residents to easily cross regional and national boundaries to access airports. Residents in Northwestern Poland, for instance, are more likely to use airports in East Germany (Berlin) than airports in Poland due to the relatively short distance, ease of ground access, porous borders, and wide choice of destinations.

3.5 Sub-region vulnerability and dependence

In order to derive the shortlisted NUT3 regions, the 278 regions with the lowest degree ratio (bottom 20% out of the full population of 1,388 sub-regions in the EEA and UK) were sorted by the population to degree ratio. The bottom 5% of the initial bottom 20% (totalling 13 regions) was taken as the final shortlist. An alternative shortlisting methodology was tested by taking the bottom 13 NUTS3 regions from the whole 1,388 population of NUTS3 regions, again sorted by the population to degree ratio. This gave the exact same list of regions up to region 14 although 17th on this list, ES300 Communidad de Madrid, had a high population to degree ratio despite having a high degree (215). Thus, taking the shortlist from the bottom 20% sample only yielded a more reliable ordering of regions overall by filtering out those regions that had a high degree. The underlying rationale for sifting the bottom 5% of the bottom 20% was to create a shortlist that had the highest disconnect between air connectivity and resident populations. In light of scarce public resources, the case for social policy intervention merely through a demonstration of access inequality can be quite weak as noted in Clifton and Lucas (2004). The case for intervention may strengthen, however, when further indications of cut-off populations, vulnerability of air service supply and dependence on air transport are built up to give a full picture and context of a particular sub-region. To test the potentiality of highly vulnerable/dependent regions in the rest of the bottom 20% (i.e. the other 265 sub-regions in the bottom 20%), four control NUTS3 regions located in the north of Scotland were selected (UKM66 – 151st, UKM61 – 185th, UKM64 – 219th, UKM65 – 243rd) to be part of the in-depth vulnerability and dependence analysis and were contrasted against the shortlisted group. The Scottish region with the lowest degree, Shetland Islands UKM66 (6 in 2019) was lower than a number of sub-regions in the shortlist but when its relatively low population is factored into the equation, its indicative position changed to 151st, well below the cut-off point for the shortlist.

The purpose of the in-depth vulnerability analysis was to take the initial vulnerability indicator of degree centrality, weighted by population and expand on it to include other considerations namely: A sub-region's reliance on one carrier, estimated based on the number of passengers brought by a carrier from all airports serving the NUTS3 region, and also a sub-region's reliance on one airport given by the percentage of air passengers using the sub-region's largest airport. The level of commitment and stability of the largest air carrier and largest airport serving a sub-region was also estimated by determining airport ownership status (public, private or mixed), airport financial stability (using a solvency debt-to-equity measure), airline ownership type (public, private or mixed), airline financial stability (debt-equity measure) and air connection stability at a sub-region's largest serving airport. The final indicator was aimed at determining the extent to which destinations have been consistently or inconsistently served from year to year over the 10 year period 2010-2019. At first glance it may be reasonable to assume that sub-regions with access to a higher degree centrality (in 2019) would be less vulnerable. It is also plausible, however, for a sub-region with a higher degree to have a lower air connection stability rating than a sub-region with a lower number of unique destinations. It may be preferable in this instance for a community to have a lower number of destinations served consistently from year to year than a more volatile number of

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destinations that are served and then not served from one year to the next.
The extended vulnerability indicators were then supplemented with any relevant comments with regards to the largest carrier and largest airport serving the region. If a region was already in receipt of some form of state aid (e.g. PSO routes, airport critical infrastructure investment support and so on in the pre-pandemic period), then this was documented and critiqued in relation to the situation in other sub-regions in the shortlist.

The dependence part of the in-depth analysis is designed to determine the extent to which a sub-region relies or depends on air transport as a sector in terms of fulfilling longer distance travel requirements and also in terms of contributions to local GDP and employment through direct air transport activity (e.g. airport activity) or through incoming tourism into the region. There are some limitations to this section due to the fact that some indicators are only collected at national or regional level but not at the sub-regional level. In the absence of sub-regional level data, regional data was used and in the absence of regional level data, national level data was used. Specifically, the indicators were nights spent at tourism accommodation establishments by foreign and nationals of a region, air transport's share of total overnight trips, journey purpose for all trips and of those taken by air, whether there is an air link from the main airport serving the sub-region to an international hub-airport or not (to help detect reliance on air transport for access to global markets) and the aviation sector's direct contribution to employment and GDP.

For the shortlisted sub-regions, to cross-check the validity of the 200km assumption used in the first stage of the analysis, travel time to the nearest hub (major) airport beyond 200km was calculated with anything below 2 hours access time, using the quickest mode of transport available, being an indication that residents have a greater level of access to air services (using an airport outside the threshold distance) than the initial stage analysis would suggest. If there was any evidence of quick access (below 2hrs) to a hub airport beyond the 200km threshold, it would be possible for a shortlisted region to be de-prioritised (see below). The centrepoint of the largest urban area of the respective sub-region was used as the origin point on google maps for this calculation, so due to the limitations of this method, de-prioritisation was only considered if 70% or more of a sub-region's population fell within 2 hours access time to the identified extra regional hub airport. Otherwise, substantial portions of sub-regional populations living within sub-regions that are only conveniently served by a smaller regional gateway and for which there was already a high population to degree ratio, would simply be ignored.

Finally, each shortlisted region was profiled for general attributes to assist the development of the case analysis and included information on regional income levels, regional population distribution, main sectors/industries, main inter-urban/long distance transport links and any pertinent information regarding neighbouring regions.

3.6 Pandemic impact on most vulnerable and dependent sub-regions

The purpose of this element was to observe the extent to which the sub-regions which were already considered vulnerable and or dependent from the previous stage findings, saw a further deterioration in air transport access during the year 2020. The impact of the pandemic on the air transport sector in Europe was felt from April 2020 onwards giving ten months of observable data up to the time of writing (through to January 2021) across 17 different sub-regions (13 shortlist and 4 benchmark region). Monthly indicators used included degree (number of unique destinations), number of airlines serving, number of passengers transported, number of flight departures offered, and average load factors across all the sub-region's largest serving airports. In order to observe the relative level of deterioration, a year-on-year baseline period of April 2019 to January 2020 was used to determine change in the above indicators. In cases where a situation deteriorated in one sub-region more than the other shortlisted sub-regions, then this was factored into the overall prioritisation list depending on the severity and longevity of the deterioration. In the unlikely event that 2020 saw a relative improvement across the pandemic indicators in a particular sub-region, then this would also be factored into the overall prioritisation list.

It is important to note that introducing covid-19 related supply and demand analysis risks an underestimation of any endemic inequalities in air access across Europe that already existed. 2019 was chosen specifically as the latest available baseline year

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to ensure that any underlying inequalities in air transport connectivity and access, which have developed over a number of decades, were very clear in the analysis. These more structural inequalities are likely to continue during the recovery and post-covid phase without exploring a range of more lasting and sustainable government and private sector interventions. An overall prioritisation list was finally generated from the preceding findings and was determined by:

- The indicative vulnerability rating (population to degree 2019)
- The in-depth and extended vulnerability analysis (2019, up to and including 2019 or nearest available year) including whether or not some level of state support was already being received in 2019
- The in-depth dependence analysis (2019 or nearest available year)
- The impact of the pandemic in 2020

A composite indicator for prioritisation was constructed as follows: Vulnerability (50% weighting), Dependence (30% weighting), impact of pandemic (20% weighting). As the impact of the pandemic is ongoing and the main focus of this paper is on the longer-term structural inequalities, a smaller weighting was given to the monthly pandemic impact in 2020. The dependence category is weighted less than vulnerability to account for the more limited access to sub-regional level data for indicators used in this category. The final score for each sub-region is calculated by the sum of individual indicators where only those indicators with a plus sign (signifying the presence of vulnerability or dependence) are counted. For numerical indicators each value is compared to the shortlist average and if above the average a plus sign is given and if below the average a minus sign is given. The limitations of adopting this non-parametric approach (e.g. giving each indicator equal weightings and comparing converting numerical indicators into a sign) are outweighed by the avoidance of making too many assumptions and the simplicity and accessibility of information and underlying methodology for the stakeholders of the research.

The Scottish benchmark group was also cross-referenced against the shortlist group as a way of checking the prioritisations methodology. If Scottish airports had more plus indicators and a higher vulnerability/dependence score overall than the shortlisted regions then this could be an indication that the initial population to degree measure from the broader analysis is not a consistently good predictor of overall vulnerability and dependence despite its usefulness if highlighting broader levels of access inequality between region. A hypothesis test (t-test) was performed to determine if the shortlist and benchmark sub-region mean differentials were significant.

3.7 Data sources used

The main data sources used for the broader first stage of the analysis were Sabre Market Intelligence version 6.5 for 2010 and 2019, used as the basis for the calculation of the degree indicator, and all airline and airport market shares; EUROSTAT/ GISCO definitions and population data for NUTS 3 regions. A wider range of sources were employed for the vulnerability and dependence stage of the analysis and included:

Vulnerability data sources:

- CAPA: Airport and airline ownership data 2019
- Various airport or airport group annual financial accounts: Debt to equity solvency ratios for airports, 2019
- Various airline or airline group annual financial accounts: Debt to equity solvency ratios for airports, 2019
- European Commission Competition DG: State aid information for airports serving sub-regions (between 2010 and 2019), number of PSO routes (2019). Two other years were also checked yielding identical results.
- Sabre: Air connections stability (destination information) between 2010 and 2019
- Google maps: Calculate quickest ground access time from largest urban area in sub-region to large hub airport located outside region (outside 200kms threshold – 2021)

Dependence data sources:

- Eurostat: Percentage of overnight trips by country (2018), number of nights spent at accommodations establishments (2019 at NUTS2 level), journey purpose (split by

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private or professional trips 2018[1] at country level), share of air transport trips in all private and professional/business trips (for trips lasting 1 night and over by country, 2018[2]), total employment (country level, 2017)

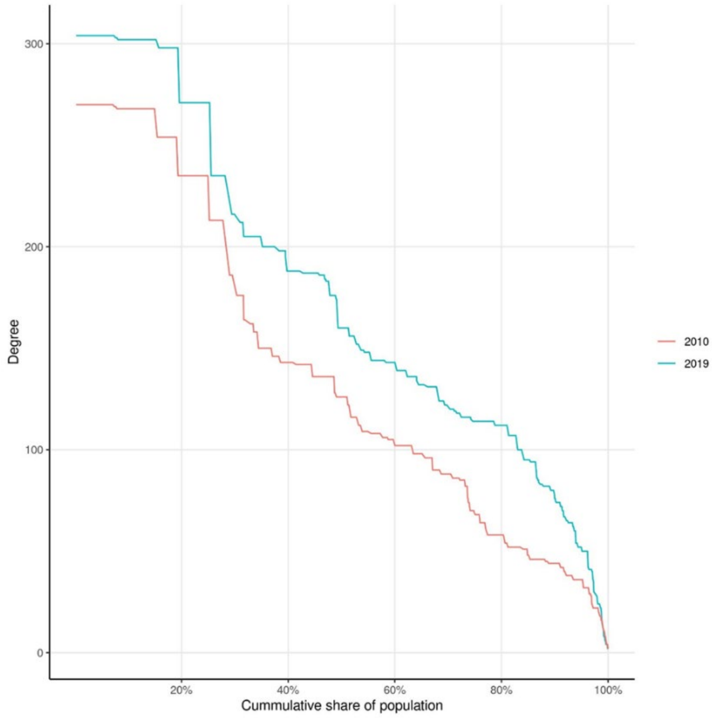
- Oxford Economics and World Bank: aviation sector contribution to GDP (2017 % of total - country level) and employment (2017 % of total - country level)

There are some limitations with the data sources used in relation to coverage (e.g. Sabre does not cover all seasonal traffic and some LCC traffic due to the lack of GDS related bookings made, though this is estimated to a high level of reliability using in-house algorithms), time period (e.g. lack of standardised time period for airport and airline annual account data), travel-data (e.g. Eurostat is missing day trips, lack of data relating solely to long-distance trips) and level of disaggregation (e.g. aviation impact information at country level only).

4. EEA-UK Region wide results and analysis

When the number of unique destinations are plotted against share of cumulated population in the years 2010 and 2019 at NUT3 level (Figure 1) it becomes clear that in 2019 there was a generally greater level of access across the EEA-UK population than in 2010. In 2010 only 64% of the continent's population had access to more than 100 unique destination, whereas by 2019 this number had jumped to 83%. At almost every level of cumulated population, there were also more connections in 2019 versus 2010 with the notable exception of the bottom 3% of population areas, where there has effectively been no change in the degree of unique destination access. There is not a directly proportional relationship between population and degree of access across the EEA-UK area. In 2019, for instance, between 40% and 50% of cumulated population, there was little change in the degree of access and a similar situation can be seen between 0% and 20% as well as 70% and 80% of cumulated populations. Conversely, there are quite big changes in degree of access between 20% and 30% of cumulated population and again between 85% and 100%.

Figure 1: Degree vs cumulative population, 2010 and 2019 (200 km threshold)



As shown in Figures 4 and 5 the greatest access to unique destinations in the EEA-UK area lies in South-East England, the Benelux countries and parts of northern France and west/central Germany and Switzerland. The geographical composition of the top 20% of NUTS3 level regions in terms of air transport access did not change between 2010 and 2019 (Figures 4 and 5). Concerning the bottom 20% of NUTS3 regions in terms of access, they are much more spread out across Europe than the top 20% with large parts of northern and western Scandanavian countries, the Baltic states, parts of southeast Europe, southern Italy, the north and west of the Iberian peninsula, southwest France, Croatia as well as pockets in Scotland and southwest Ireland all featuring (Figures 2 and 3). Unlike the top 20%, the composition of the bottom 20% has somewhat changed with a larger number of sub-regions in Spain, France and the Baltic countries featuring in the bottom 20% in comparison to 2010 and fewer sub-regions featuring from eastern Europe. Although the scale of access has increased for those regions in the bottom 20% during the 2010-2019 period, it can be observed that not all regions have increased at the same rate or indeed benefitted to the same extent from additional destinations. Figure 6 includes an

[1] 2013 for UK regions and 2017 for Swedish regions

[2] 2013 for UK regions and 2017 for Swedish regions

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overall heatmap of the 2019 degree indicator, covering all observed NUTS3 level sub-regions and the top 20 airports represented by bubble size.

Figure 2: Bottom 20% at EU27+UK+EEA level, 2019 (200 km threshold)

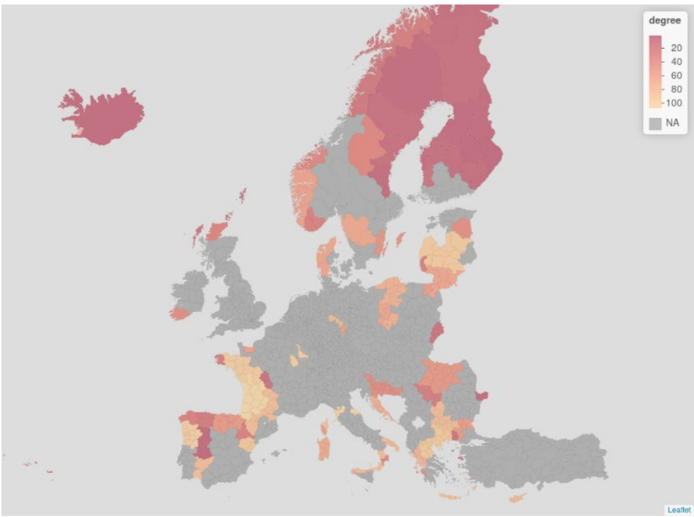

Figure 3: Bottom 20% at EU27+UK+EEA level, 2010 (200 km threshold)

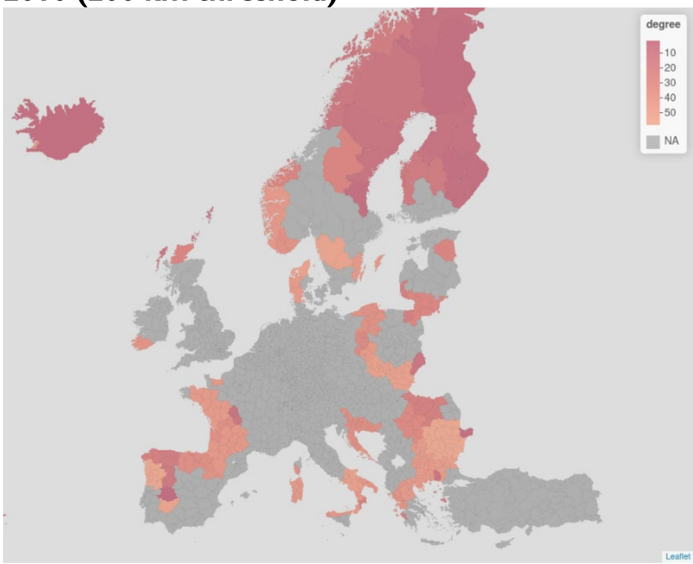

Figure 4: Top 20% at EU27+UK+EEA level, 2019 (200 km threshold)

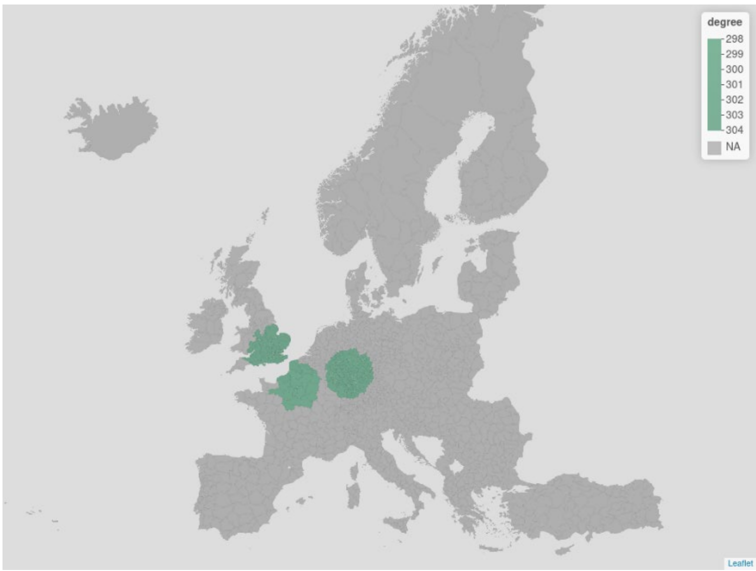

Figure 5: Top 20% at EU27+UK+EEA level, 2010 (200 km threshold)

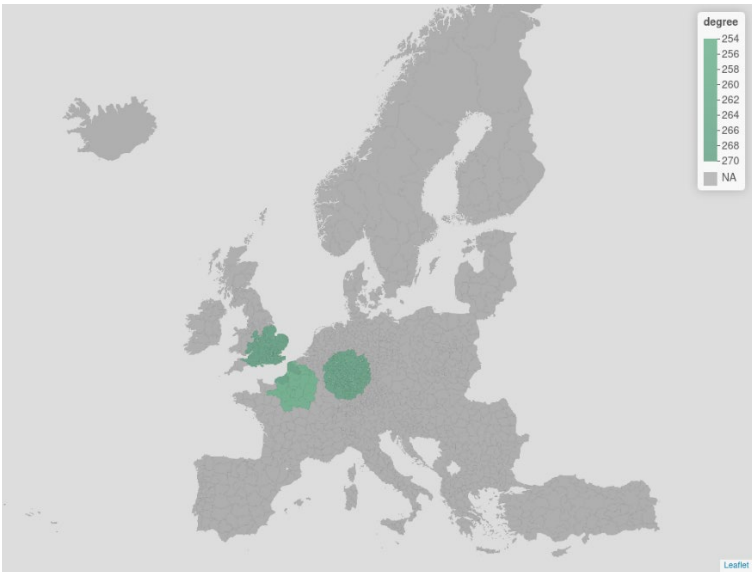

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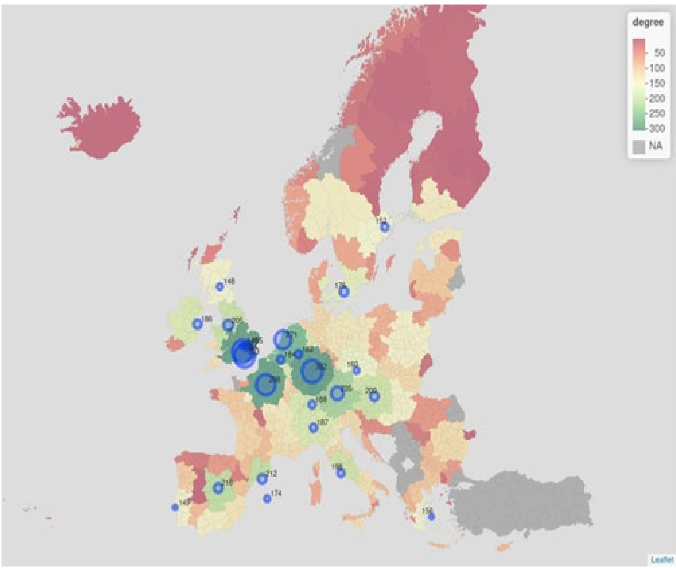
Figure 6: Degree indicator for all NUTS3 sub regions and top 25 airports, 2019 (200 km threshold)



20:20 crude inequality ratios by EEA-UK country have been reported in Table 1. Countries are sorted from largest to smallest by 20:20 inequality ratio. Due to the fact that one sub-region had no direct connectivity at all within a 200km range (LV005), Latvia appears as the most unequal on the list despite the average degree in the top 20% of sub-regions in the country having a degree of 101. Finland has a reported degree 20:20 ratio of 38. This means that the top 20% of sub-regions in Finland are on average 38 times more connected than residents living in the bottom 20% of sub-regions in Finland. Sweden, Iceland, Spain and Norway all have ratios above 7. The Netherlands, Belgium, Switzerland, Ireland, Czech Republic, Austria and Hungary all have 20:20 ratios below 2, which is indicative of generally equal levels of access across each of these states. The 20:20 degree ratio in itself does not indicate whether higher levels of access equality are generally at a high or level, however. In Ireland, for instance, equality is present at a lower level of connectivity Sub-regions in Belgium and the Netherlands generally have the most desirable outcome given the generally high and equal levels of air transport access in 2019 (a result of the two countries small size and the existence of two airports with a large number of connections).

The highlighted countries, as detailed in section 5, also feature shortlisted sub-regions so generally speaking those countries that feature quite highly in terms of country level degree inequality, also tend to have individual sub-regions with some of the most prevalent air transport access issues across the whole continent. Iceland and Norway have generally high levels of inequality. In the case of Norway the country level bottom 20% average is notably higher than it is for other Scandinavian countries like Sweden and Finland. Without a well-established network of supported PSO routes, it is possible that the average degree for the bottom 20% in Norway would have been more similar to that of Sweden and Finland. Iceland is something of an outlier in that it is a peripheral island state in a similar way to Cyprus but its land mass is much bigger meaning that the two reporting sub-regions are also much larger in area. For statistical purposes, the country is split into the Capital region (IS001) and the rest of the island (IS002 Landsbyggð), which naturally leads to a greater access inequality level with the country's two main airports both located in the capital region. Romania and Poland have generally lower levels of inequality despite having one sub-region each making it into the shortlisted sample of regions (detailed in Section 5).

Table 1: Crude inequality ratio by degree 20:20 ratio at country level (2019 data)

Country	Number of N3 regions	Average degree in country bottom 20%	Average degree in country top 20%	Ineq ratio country (top20/bot20) by degree	Average pop:degree country level bottom 20%	Average pop:degree top country level 20%	Ineq ratio country (top20/bot20) by pop:degree	NUTS3 regions in final shortlist
Latvia	6	0	101	N/A	0	2,023	N/A	1
Finland	19	4	152	38	79,476	979	81.18	4
Sweden	21	7	186	26.57	47,356	1,151	41.14	2
Iceland	2	4	75	18.75	32,190	3,043	10.58	0
Spain	59	31	220	7.1	55,325	661	83.7	4
Norway	17	20	141	7.05	9,562	1,344	7.11	0
Romania	42	24	126	5.25	24,996	2,406	10.39	1
France	96	78	373	4.78	11,275	1,011	11.15	0
Croatia	21	33	155	4.7	14,796	903	16.39	0
Estonia	5	38	177	4.66	8,348	830	10.06	0
Denmark	11	61	204	3.34	9,538	772	12.35	0
Italy	110	88	271	3.08	8,638	817	10.57	0
Slovenia	12	69	207	3	3,580	443	8.08	0
Greece	52	59	172	2.92	4,895	416	11.77	0
UK	179	148	428	2.89	2,782	570	4.88	0
Poland	73	66	186	2.82	10,138	2,077	4.88	1
Germany	401	145	392	2.7	2,006	242	8.29	0
Portugal	25	71	182	2.56	11,034	636	17.35	0
Bulgaria	28	58	140	2.41	8,004	830	9.64	0
Lithuania	10	53	115	2.17	10,628	1,169	9.09	0
Slovakia	8	120	241	2.01	6,773	2,390	2.83	0
Hungary	20	120	234	1.95	8,811	1,200	7.34	0
Austria	35	169	307	1.82	2,902	221	13.13	0
Czech Republ	14	155	252	1.63	8,355	1,959	4.26	0
Ireland	8	123	196	1.59	9,861	1,812	5.44	0
Switzerland	26	238	325	1.37	3,363	111	30.3	0
Belgium	44	304	410	1.35	1,689	179	9.44	0
Netherlands	40	310	407	1.31	2,505	387	6.47	0
Malta	2	135	135	1	3,409	247	13.8	0
Cyprus	1	97	97	1	9,029	9,029	1	0
Liechtenstein	1	322	322	1	119	119	1	0
Average	**44.8**	**102**	**224**	**5.4**	**13,270**	**1,290**	**15.5**	

Source: Sabre Market Analytics

The average inequality value at the country level is 5.4 with generally good levels of access within 200kms to 102 unique destinations on average in the

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bottom 20% and 224 unique destinations in the top 20%. However, if the 20:20 ratio is recalculated for the population to degree ratio then the average value increased to 15.5. There is an average of 13,270 residents for every unique destination available in the country level bottom 20% versus only 1,290 residents per degree for sub-regions located in the country level top 20% though a limitation to this average is that some countries have a higher number of NUTS3 regions (e.g. Germany), leading to a smaller number of residents per unique destination versus those countries that report the NUTS3 level at a greater area. This difference can primarily be explained, however, by the finite number of unique destinations and routes that can be offered, particularly intra-continentally and by variations across different sub-regions in air travel propensities. If countries are re-sorted according to this 20:20 indicator, then Spain, Finland, Switzerland, Portugal and Croatia would feature in the top 5 most unequal countries in terms of air access. At the country level, degree is thought to be a more reliable 20:20 ratio inequality indicator than population to degree, however, due to the fact that some sub-regions located close to very large sub-regions within 200kms end up with a very low number of residents for every unique destination. In Switzerland, for example, the top 20% country level sub-regions (representing 5 sub-regions) averages out at as few as 111 residents per unique destination.

It is also of interest to look at the relative number of unique connections between rather than within member countries. Rather strikingly, when the top 20% and bottom 20% of regions are averaged out by country (of a total of 31 countries), the ratio between the top and bottom 20% is only 3.6 for the top 20% of sub-regions across EEA-UK states, whereas the ratio is as much as 25 for the bottom 20%. For some countries the bottom 20% average was as high as 250 unique connections where as for other countries it was as low as 10 (i.e a ratio of 25). Conversely, for some countries the top 20% average was as high as 389 unique connections whereas there were 108 for countries with the lowest top 20% average. This clearly indicates a much wider spread in direct connectivity at the bottom end and a high level of between country inequalities particularly at the bottom 20% level. Compared to countries like Sweden, Finland, Latvia, Norway, Romania and Spain, the level of access for bottom 20% sub-regions in countries like Germany, UK, Austria, Switzerland, Belgium and Netherlands is significantly higher, strongly supporting the idea that at the EEA-UK aggregate level the case for inequality related intervention is much lower in these countries in comparison to those that are typically featured in the shortlist sub-region analysis (section 5).

5. Shortlist region vulnerability and dependence results and analysis

Table 2 shows a comparison of the simple degree shortlist versus the final selected population to degree ratio shortlist. It also shows four Scottish sub-regions in the bottom 20% of sub-regions as the selected benchmark group. The highlighted sub-regions are the same independent of the sorting method (degree or population/degree) adding weight to the need to examine those sub-regions further. HR04C in Croatia was disregarded because its population to degree ratio put it into 14th position (just outside the shortlist cut-off point). It is also possible for residents of this sub-region, for example, those living in Vinkovchi to access Belgrade International airport by car in less than 2 hours by car and under 200km. This airport was not linked to this area by the initial stage analysis given that Serbia is not an EU/EEA country and therefore not in the statistical population of NUTS3 sub-regions. The other region with a very low degree to be discarded was FI1D8, Kainuu Finland on account of its low population to degree ratio. An additional Spanish region (La Coruña – ES111) and a Polish region (Chelmsko-zamojski – PL812) were included in the shortlist given their higher population to degree ratios despite having 29 and 16 unique connections through the airports located within 200 km range. The inclusion of these two sub-regions with higher degree centrality also allowed for further cross-checking against bottom 20% sub-regions that have been left out of the shortlist, in addition to the Scottish benchmark group.

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Table 2: Selected shortlist of sub-regions for in-depth V/D analysis

Country	N3 region	Degree	Largest Airline	Airline Share	Largest Airport	Airport Share	N3 Name	Population	Ratio pop:degree
Latvia	LV005	0	NONE	0.00%	NONE	0.00%	Latgale	260,226	
Spain	ES432	2	IB	100.00%	BJZ	100.00%	Caceres	392,931	196,466
Spain	ES415	2	FR	69.80%	VLL	100.00%	Salamanca	332,234	166,117
Finland	FI1D2	2	AY	95.80%	KUO	39.30%	Pohjois-Savo	245,602	122,801
Sweden	SE313	3	SK	49.70%	SDL	71.30%	Gavleborgs lan	286,547	95,516
Spain	ES419	2	FR	57.90%	VLL	83.00%	Zamora	173,632	86,816
Finland	FI1D3	2	AY	94.90%	KUO	47.60%	Pohjois-Karjala	162,240	81,120
Romania	RO225	3	W9	67.80%	CND	100.00%	Tulcea	194,421	64,807
Finland	FI1D9	7	AY	66.50%	OUL	53.30%	Pohjois-Pohjanmaa	412,161	58,880
Finland	FI193	5	AY	58.40%	TMP	32.80%	Keski-Suomi	275,521	55,104
Sweden	SE332	6	SK	49.70%	LLA	67.70%	Norrbottens lan	250,497	41,750
Spain	ES111	29	VY	29.70%	SCQ	58.30%	A Coruña	1,122,006	38,690
Poland	PL812	16	FR	45.60%	RZE	64.00%	Chelmsko-zamojski	615,481	38,468
Latvia	LV005	0	NONE	0.00%	NONE	0.00%	Latgale	260,226	
Spain	ES432	2	IB	100.00%	BJZ	100.00%	Caceres	392,931	196,466
Spain	ES415	2	FR	69.80%	VLL	100.00%	Salamanca	332,234	166,117
Finland	FI1D2	2	AY	95.80%	KUO	39.30%	Pohjois-Savo	245,602	122,801
Spain	ES419	2	FR	57.90%	VLL	83.00%	Zamora	173,632	86,816
Finland	FI1D3	2	AY	94.90%	KUO	47.60%	Pohjois-Karjala	162,240	81,120
Sweden	SE313	3	SK	49.70%	SDL	71.30%	Gavleborgs lan	286,547	95,516
Romania	RO225	3	W9	67.80%	CND	100.00%	Tulcea	194,421	64,807
Croatia	HR04C	4	EW	32.70%	OSI	100.00%	Vukovarsko-srijemsk	152,494	38,124
Finland	FI193	5	AY	58.40%	TMP	32.80%	Keski-Suomi	275,521	55,104
Finland	FI1D8	5	AY	70.30%	OUL	72.40%	Kainuu	73,061	14,612
Sweden	SE332	6	SK	49.70%	LLA	67.70%	Norrbottens lan	250,497	41,750
UK	UKM66	6	LM	100.00%	KOI	51.10%	Shetland Islands	23,125	3,854
UK	UKM64	15	U2	39.80%	INV	84.10%	Western Isles	26,688	1,779
UK	UKM65	16	U2	35.30%	INV	74.60%	Orkney Islands	22,055	1,378
UK	UKM61	36	KL	17.80%	ABZ	68.40%	Caithness, Sutherland, Ross & Cromarty	94,917	2,637

Source: Sabre Market Analytics and Eurostat

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The largest airline and their respective share along with the largest airport and its respective share of O&D passengers linked to each sub-region are also shown in Table 2. Regions like Caceres have a high reliance on one airport (Barajoz – BJZ) and one air carrier (Iberia – IB) within 200km of the sub-region centroid point, whereas regions like Keski-Suomi in Finland display a less concentrated reliance on the largest airline (SAS – SK) and airport (Tampere – TMP) serving that sub-region. The raw population is also given for 2019. All shortlisted sub-regions have substantial local populations, an indication that they are not remote, sparsely populated areas, though due to the size of some NUTS3 regions, population density may be quite low despite a larger population overall (e.g. FI1D3 population density of only 11.3 inhabitants/km2). Lower populated sub-regions such as Powys in Wales, UK (UKL24 - population 132,000) did not make it into the initial bottom 20% of sub-regions on account of its less than 200km proximity to Manchester Airport (MAN – degree 221 in 2019). If it were to make it into the bottom 20%, its chances of being shortlisted were also negligible owing to its already low population to degree ratio of 598. Another example is Lungau in Austria (sub-region AT321) with less than 200km access to Munich Airport (MUC), for example, and a 2019 degree of 244 leading to the sub-region falling far outside the bottom 20% and with a population to degree ratio of only 83.

A regional profile was created for each shortlisted and benchmark sub-region (see Appendix A) giving a short description of each sub-region's GDP per capita in comparison to EU27 and country levels (using 2018 data) along with a general summary of notable transport links, economic sectors and population characteristics. Although, from the first stage of the analysis it is clear that sub-regional populations per degree are all relatively high, some sub-regions have more evenly distributed populations with generally smaller urban centres (e.g. Pohjois-Savo, Finland and Caithness and Sutherland and Ross and Comarthy, Scotland, UK) whilst others have more concentrated populations located in a particular area of a sub-region (e.g. Norrbottens län and Gävleborgs län, Sweden and Zamora in Spain). This impacts on access time and levels of perceived air travel convenience. Gavleborg Ian's substantial population, for example, is quite concentrated towards the southern part of the sub-region with Gavle (102,000 inhabitants) and Sandvikien (39,000 inhabitants) both located closer in drive time to the larger Stockholm Arlanda airport (ARN 2019 degree = 177) than to the much smaller Sundsvall-Timra Airport (SDL 2019 degree = 3). That said, 45% of the sub-region's population is located in the more Northern coastal areas of the sub-region and more spread out than the southern part (Figure 7).

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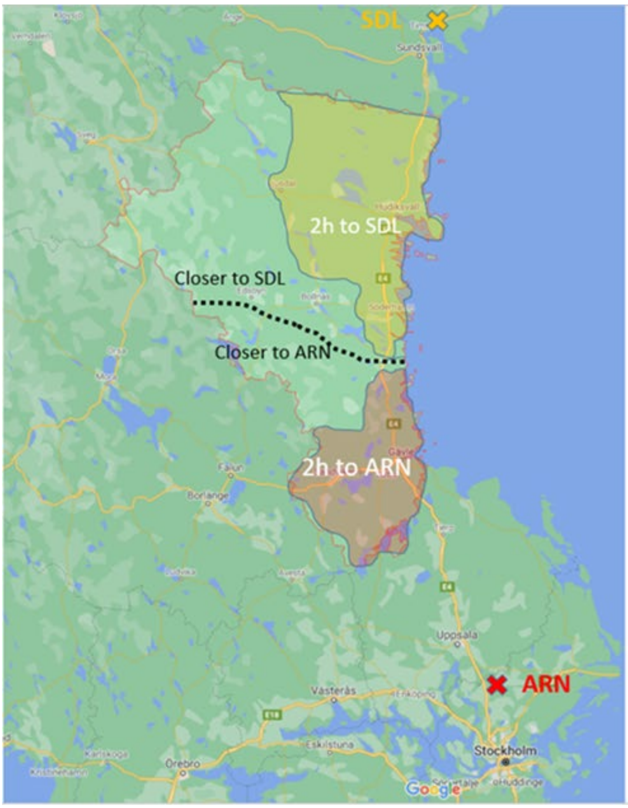
Figure 7: Map, population and airport data related to the Gävleborgs län sub-region



County	Population (000)	Served by	
Gavle	102	ARN	
Ljusdal	19	SDL	
Sandvikien	39	ARN	
Hudiksvall	38	SDL	
Bollnas	27	SDL	
Soderhamn	26	SDL	
Hofors	10	ARN	
Nordanstig	9	SDL	
Ockelbo	6	ARN	
Ovanaker	12	SDL	
TOTAL NUTS 3 REGION	**288**		
		TOTAL ARN (%)	55%
		TOTAL SDL (%)	45%

55% of population of Gavleborgs lan (NUTS3 region) lives closer to Stockholm Arlanda than Sundsvall- Timra airport (measured in drive-time)

Source: Developed by authors

Propensity to travel may be affected by low relative incomes in a sub-region (GDP per capita), though due to the stimulation effect of air transport as well as arguments related to social obligations to keep substantially populated areas well-connected, evidence of low income levels is not justification in itself for air connectivity levels to be highly unequal. The Latvian, Polish and Romanian shortlisted sub-regions had the lowest relative GDP per capita in comparison to average country and EU27 levels whereas the benchmark Scottish regions, Swedish and Finnish sub-regions had the highest relative GDP per capita levels at the sub-regional level (Appendix A). Some of the shortlisted regions had an economic reliance towards primary industries (e.g. Western Isles, Scotland), which tend to lead to a lower demand for air access, whereas other regions clearly have a large and/or growing reliance on service industries including tourism, which naturally have a closer symbiotic relationship with air transport. La Coruña, Salamanca and to a lesser extent three of the four benchmark Scottish sub-regions had a moderate to high reliance on service sectors and tourism-education.

For increased visibility, the same methodologies were applied to give an indicative shortlist within the top 20% of sub-regions in terms of degree centrality. The top 5% of the top 20% (i.e. an indicative shortlist of 13 sub-regions), give an initial indication of those sub-regions that are considered to be least vulnerable or least in need of state intervention (Table 3). Sorting by degree centrality only, sub-regions in Germany, the UK, and France all feature prominently as all are served by large and multiple airports, a diverse range of air carriers and a high number of unique destinations. Four sub-regions in Germany namely, Monchengladbach/Kreisfreie Stadt, Rhein-Kreis Neuss, Mettmann and Dusseldorf/Kreisfreie Stadt can actually access the highest number of unique destinations from Amsterdam, being located within 200km of this airport despite being in a different country. The low concentration (31%) of all traffic from these regions on AMS demonstrates that people living in these central-western sub-regions of Germany have a great choice of airports including Dusseldorf (DUS) and Cologne-Bonn (CGD) within Germany itself. Due to both Paris and London airports being within 200kms of the Pas-de-Calais sub-region, residents living there had access to over 450 unique destinations in 2019.

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Some Southeast England sub-regions also made it into the shortlist of indicatively least vulnerable sub-regions, particularly those with access to London airports that are also close enough to airports in the midlands or the south-west to have yet more choice of destinations within 200kms. The shortlist of least vulnerable areas was also sorted by the population to degree ratio. Unlike the bottom 20% shortlists, there were no common sub-regions between those sorted by simple degree and those sorted by population to degree. Landlocked sub-regions of Switzerland and Austria that are much less densely populated than areas in Germany, France and the UK but still with high access to multiple large and well-served airports in Zurich, Munich, Vienna and Geneva amongst others within 200kms leads to very low population to degree ratios – 50 in the case of Appenzell in Switzerland, a sub-region with a total population of only 16,145. In fact, using the population to degree method led to more unreliable results given the number of sub-regions with comparatively low populations that have very good levels of air transport connectivity. For the least vulnerable regions, using the simple degree sorting method is therefore considered a more reliable sorting method.

Table 3: Least vulnerable sub-regions (i.e. those least in need of in-depth V/D analysis)

Country	N3 region	Degree	Largest Airline	Largest Airline Share	Largest Airport	Largest airport share	N3 Name	Population	Ratio population:degree
Germany	DEA15	463	LH	19%	AMS	31%	Monchengladbach, Kreisfreie Stadt	261,454	565
Germany	DEA1D	463	LH	19%	AMS	31%	Rhein-Kreis Neuss	451,007	974
Germany	DEA1C	463	LH	19%	AMS	31%	Mettmann	485,684	1,049
Germany	DEA11	463	LH	19%	AMS	31%	Dusseldorf, Kreisfreie Stadt	619,294	1,338
France	FRE12	451	AF	22%	CDG	39%	Pas-de-Calais	1,457,843	3,232
Germany	DEA16	446	LH	20%	AMS	33%	Mulheim an der Ruhr, Kreisfreie Stadt	170,880	383
Germany	DEA32	446	LH	20%	AMS	33%	Gelsenkirchen, Kreisfreie Stadt	260,654	584
Germany	DEA13	446	LH	20%	AMS	33%	Essen, Kreisfreie Stadt	583,109	1,307
Germany	DEA55	433	LH	22%	AMS	37%	Herne, Kreisfreie Stadt	156,374	361
UK	UKK13	431	BA	20%	LHR	34%	Gloucestershire	635,249	1,474
UK	UKJ14	431	BA	20%	LHR	35%	Oxfordshire	687,466	1,595
UK	UKG32	430	BA	19%	LHR	34%	Solihull	215,055	500
UK	UKJ12	430	BA	20%	LHR	34%	Milton Keynes	271,677	632
Switzerland	CH054	323	LX	17%	ZRH	33%	Appenzell I. Rh.	16,145	50
Austria	AT321	244	LH	48%	MUC	88%	Lungau	20,320	83
Spain	ES703	122	FR	18%	TFS	68%	El Hierro	11,154	91
Germany	DEB3A	355	LH	38%	FRA	63%	Zweibrucken, Kreisfreie Stadt	34,209	96
Austria	AT331	293	LH	27%	MUC	48%	Ausserfern	32,670	112
Germany	DEG04	312	LH	54%	FRA	92%	Suhl, Kreisfreie Stadt	34,835	112
Germany	DEB37	355	LH	38%	FRA	63%	Pirmasens, Kreisfreie Stadt	40,403	114
Germany	DE255	353	LH	49%	FRA	53%	Schwabach, Kreisfreie Stadt	40,792	116
Germany	DE251	355	LH	49%	FRA	52%	Ansbach, Kreisfreie Stadt	41,847	118
Liechtenstein	LI000	322	LX	17%	ZRH	32%	Liechtenstein	38,378	119
Switzerland	CH064	313	U2	21%	ZRH	29%	Obwalden	37,841	121
Switzerland	CH062	301	LX	18%	ZRH	35%	Uri	36,433	121

Source: Sabre Market Analytics, Eurostat

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In observing the other extreme across the full dataset, it is possible at this point to highlight the apparent vulnerability of the shortlisted sub-regions as shown in Table 2. There are good reasons as to why the sub-regions listed in Table 3 have much higher levels of access than those in Table 2, chiefly among them the higher levels of underlying economic activity, but there are also sub-regions that have clearly benefitted from locational and agglomeration benefits, which despite their smaller apparent population size, are able to enjoy much higher levels of access than the shortlisted regions, despite their substantial populations.

6. Impact of pandemic and overall prioritisation estimates

The pandemic has adversely affected the whole aviation sector and the ability to travel even for essential reasons has been severely hampered and inconvenienced for residents in all sub-regions. An ACI Europe press release in March 2021 (ACI Europe, 2021) highlighted, however, that most of the 193 European airports facing insolvency in Spring 2021 are regional airports. Thus, residents located in sub-regions that are already in the bottom 20% of connectivity (population to degree ratio), are often particularly vulnerable, given the likeliness of gaps in essential links to open up as air carriers look to retrench and focus on core/denser routes from their base/hub airports (in the absence of state-aid).
Figures 8 and 9 show a 2-year trend (January 2019 to January 2021) in the number of unique destinations and flight departures for the shortlisted sub-regions' largest airports. Unique destinations were already quite low for most of the observed airports with further reductions noted from Spring 2020. VLL had a small rebound over the summer of 2020 as travel restrictions were temporarily eased but it went back down again in the Autumn of 2020. For the two larger airports in the shortlist (SCQ and RZE) big drop offs were noted in April 2020 followed by partial rebounds in traffic in summer 2020. Number of destinations levelled off again in the autumn 2020 to levels that were somewhat below autumn 2019 levels. This graph shows that airports like SCQ and RZE and by extension their sub-regional populations are more likely to see traffic rebounds when travel restrictions are eased in comparison to the other shortlisted airports/sub-regions, though it is also recognised that summer 2020 capacity could have been increased by carriers on some routes due to a more limited number of destination to fly to (e.g. LOT launching five seasonal routes from RZE in summer 2020 after having not considered this in previous years).

Figure 8: Development of degree centrality across shortlisted regions' largest airports (<200km) Jan 19-Jan 21

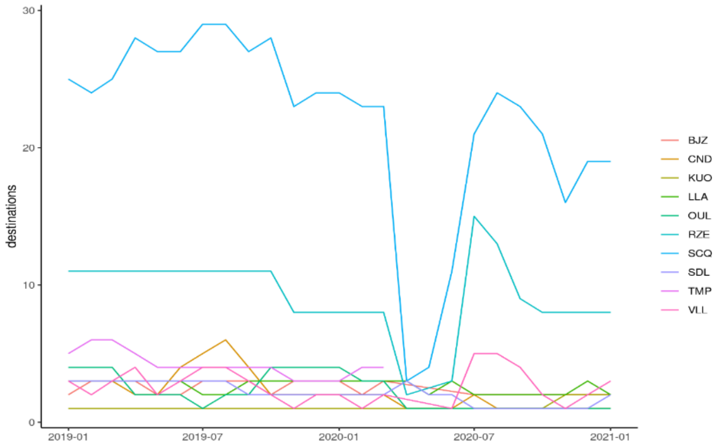
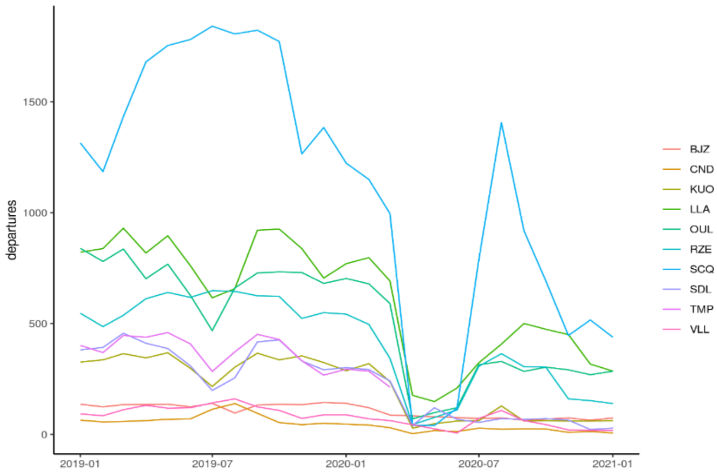


Figure 9: Development of monthly flight departures across shortlisted regions' largest airports (<200km) Jan 19-Jan 21



The number of flight departures (Figure 9) shows a slightly higher level for the smaller shortlisted airports in comparison to SCQ. Lulea Airport (LLA) in the Norbottens lan sub-region (SE332) for instance, had a higher number of flight departures using on average smaller aircraft gauges than airports like RZE. Frequencies at LLA rebounded in the summer of 2020 and then tailed off again in the autumn 2020 as the second wave of Covid-19 hit. Though partially obscured by the scale of the chart, the smaller airports in terms of frequency in 2019 (e.g. VLL) did not see such a dramatic reduction in April 2020 but also did not see much of a recovery in summer 2020 either, which is indicative of a preceding underlying difficulty in attracting services

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irrespective of the impact of the pandemic and also the difficulty in securing a recovery for these airports, even when travel restrictions are relaxed.

Table 4: Most vulnerable/dependent sub-regions for prioritisation

#	Country	NUTS3 region	NUTS 3 region name	Largest serving airport (<200km)	*Relative percentage score dependence (% plus)	*Relative percentage score vulnerability (% plus)	*Relative percentage score pandemic impact (% plus)	*Relative percentage score overall V/D score (% plus)
1	Latvia	LV005	Latgale	None	28.6	100	100	78.6
2	Spain	ES415	Salamanca	VLL	57.1	88.9	40	69.6
3	Finland	FI1D2	Pohjois-Savo	KUO	57.1	66.7	80	66.5
4	Finland	FI1D3	Pohjois-Karjala	KUO	57.1	55.6	80	60.9
5	Spain	ES419	Zamora	VLL	57.1	66.7	40	58.5
6	Finland	FI1D9	Pohjois-Pohjanmaa	OUL	57.1	44.4	90	57.4
7	Spain	ES432	Caceres	BJZ	42.9	66.7	50	56.2
8	Sweden	SE313	Gävleborgs län	SDL	42.9	44.4	90	53.1
9	Spain	ES111	A Coruña	SCQ	57.1	44.4	40	47.4
10	Romania	RO225	Tulcea	CND	80	0	55.6	43.8
11	Finland	FI193	Keski-Suomi	TMP	42.9	33.3	30	35.5
12	Sweden	SE332	Norrbottens län	LLA	42.9	33.3	10	31.5
13	Poland	PL812	Chelmsko-zamojski	RZE	0	33.3	20	20.7
Average shortlisted sub-regions					**41.8**	**56.4**	**57.7**	**52.3**
1	UK	UKM66	Shetland Islands	KOI	71.4	55.6	60	61.2
2	UK	UKM64	Western Isles	INV	57.1	44.4	40	47.4
3	UK	UKM65	Orkney Islands	INV	57.1	44.4	40	47.4
4	UK	UKM61	Caithness & Sutherland and Ross & Cromarty	ABZ	57.1	33.3	30	39.8
Average benchmark Scottish sub-regions					**60.7**	**44.4**	**42.5**	**48.9**

*Notes: Relative to shortlisted region mean average values. Vulnerability score composed of 10 indicators (weighted 50% of total score), Dependence 7 indicators (weighted 30% of total score) and Pandemic impact 10 indicators (weighted 20% of total score)

The level of relative vulnerability and dependence between the shortlisted sub-regions varies from 21% (PL812) to 79% (LV005) [Table 4]. Residents in Latgale (LV005) effectively have no convenient access to any airports within 200km with the nearest airports beyond this threshold being Riga International Airport (RIX), which is a 3-hour drive away (235kms) from the region's largest urban area, Daugavpils. Alternatively, residents can also access Vilnius International Airport (VNO) at just over 200kms distance by road and just under 3 hours' drive time. The absence of any regional airport option has led to maximum relative vulnerability scores for LV005. The before and after pandemic situation logically stayed at the same low level for LV005, so it received maximum scores for pandemic impact given the additional strain Covid-19 has put on scarce public resources and the more remote possibility of any improvement in local air transport access for Latgale residents any time soon, though according to LSM.LV (2021), some preliminary state funding of 100,000 euros has been awarded for geological survey and pre-project exploration of an airport site located at Lociki. The relative dependence score of this sub-region was low due to its comparatively low dependence on air transport related employment, GDP and incoming tourism. It may be the case that improved services into Riga and/or Vilnius would have a partially positive knock-on effect on access levels to LV005. LV005 highest priority level in the shortlist group could therefore be viewed with some caution in light of this. The other sub-regions in the top 5 in order of priority are either served by Valladolid (VLL) in Castille and Leon, Spain or by Kuopio (KUO) in the Siilinjarvi area of Finland as the largest airports serving residents of these areas within 200kms. This applies to two sub-regions in Spain; Salamanca (ES415) and Zamora (ES419) both served by VLL and two sub-regions in Finland; Pohjois-Savo (FI1D2) and Pohjois-Karjala (FI1D3). The two Finnish sub-regions have been particularly impacted during the Covid-19 period, with deteriorations in 80% of the pandemic indicators relative to the shortlist mean average. Vulnerability and dependence scores also feature quite highly for both sub-regions with FI1D2's higher vulnerability score being the only area separating two Finnish regions on account of the fact that for every unique destination there are 122,800 residents in Savo versus 81,100 in Karjala. The two Spanish sub-regions have not seen relative service levels reduce as much during the observed pandemic period, but were both looking particularly vulnerable pre-pandemic anyway with 89% and 67% of vulnerability indicators considered more vulnerable than the shortlist mean average in Salamanca and Zamora respectively. A high reliance on footloose, privately owned Ryanair, a low degree centrality, a lack of existing state-aid measures (in 2019), a high population per unique destination (166,000) in the VLL area and a comparatively low air connection stability (73%) all combine to give Salamanca a higher vulnerability score. Zamora, being served primarily by the same airport (VLL), only had a lower score than Salamanca due to its lower population to degree ratio of 86,800. With dependence on air transport also being moderately high in all four of these Spanish and Finish regions, compared to the shortlist average, the case for prioritisation increases further.

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Table 5 shows t-test results for the overall V/D scores, along with pandemic impact, vulnerability and dependence tested separately. All tests show that there is not enough statistical evidence to suggest that the benchmark group of Scottish sub-regions in the UK are not as vulnerable, dependent or as impacted by the pandemic as the shortlist group of sub-regions. This departs from the original hypothesis and can be partly explained by the benchmark group's higher dependence on air transport in comparison to the shortlist group. This dependence test was the only significant one at the 95% confidence level, which suggests that the relative dependence for the Scottish sub-regions versus the mean average of the shortlist sub-region group of 61% (range 71% to 57%) was higher than the shortlist group of 42% (though with a higher range of 0% to 80%).

Table 5: Student t-test results: shortlist versus benchmark sub-region V/D and pandemic impact

t-Test: Two-Sample Assuming Unequal Variances- total V/D and P score		
Shortlist (n=13)		*Benchmark (n=4)*
Mean	0.52	0.49
Variance	0.03	0.01
df	10	
t Stat	0.53	
P(T<=t) on	0.31	
t Critical on	1.81	
t-Test: Two-Sample Assuming Unequal Variances - Dependence score		
Shortlist (n=13)		*Benchmark (n=4)*
Mean	0.42	0.61
Variance	0.04	0.01
df	14	
t Stat	-2.81*	
P(T<=t) on	0.01	
t Critical on	1.76	
t-Test: Two-Sample Assuming Unequal Variances - Vulnerability score		
Shortlist (n=13)		*Benchmark (n=4)*
Mean	0.56	0.44
Variance	0.04	0.01
df	13	
t Stat	1.62	
P(T<=t) on	0.06	
t Critical on	1.77	
t-Test: Two-Sample Assuming Unequal Variances - Pandemic impact		
Shortlist (n=13)		*Benchmark (n=4)*
Mean	0.58	0.43
Variance	0.09	0.02
df	13	
t Stat	1.46	
P(T<=t) on	0.08	
t Critical on	1.77	

Note: *significant at the 95% confidence level

For a number of reasons, namely the high number of unique destinations in regions with good access to SCQ (ES111) and RZE (PL812) in comparison to the other shortlisted sub-regions, their comparatively low V/D scores of 47% and 21%, and also the rather notable rebound in departures and destinations at both RZE and SCQ in the summer of 2020 during the pandemic, ES111 and PL812 were added to the benchmark list of Scottish sub-regions, leading to a revised shortlist of 11 sub-regions and a revised benchmark list of six sub-regions. Averages for all V/D and pandemic impact indicators were recalibrated and all regions were scored against these revised averages. The results of this process are shown in Table 6. Compared to the results shown in the original prioritisation list (Table 5), a very similar top 5 sub-regions are present with the Spanish sub-regions of Salamanca and Zamora (now in 6th) reliant on Valladolid airport, featuring prominently, but on this occasion the region of Caceres, served primarily by Badajoz (BJZ) airport has entered into the top 5. Due to a larger pandemic impact, the two Finnish regions (80% of pandemic impact indicators below the mean average across the revised shortlist group), already featuring in the top 5, surpassed the Salamanca region in Spain with an overall score of 63% in Savo and 58% in Karjala.

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Table 6: Revised most vulnerable/dependent sub-regions for prioritisation

#	Sub-region	Total V/D score	*Dependence score (% plus)	*Vulnerability score (% plus)	*Pandemic impact (% plus)
	Revised shortlist group				
1	LV005 - Lagtale	78.60%	28.60%	100.00%	100.00%
2	FI1D2 - Pohjois-Savo	63.10%	57.10%	60.00%	80.00%
3	FI1D3 - Pohjois-Karjala	58.10%	57.10%	50.00%	80.00%
4	ES415 - Salamanca	56.10%	57.10%	70.00%	20.00%
5	ES432 - Caceres	52.90%	42.90%	60.00%	50.00%
6	ES419 - Zamora	51.10%	57.10%	60.00%	20.00%
7	SE313 - Gävleborgs län	45.90%	42.90%	30.00%	90.00%
8	FI1D9 - Pohjois-Pohjanmaa	40.10%	57.10%	30.00%	40.00%
9	RO225 - Tulcea	34.00%	0.00%	40.00%	70.00%
10	SE332 - Norrbottens län	27.90%	42.90%	30.00%	0.00%
11	FI193 - Keski-Suomi	24.90%	42.90%	20.00%	10.00%
	Revised shortlist averages	**48.40%**	**44.20%**	**50.00%**	**50.90%**
	Revised benchmark group				
1	UKM66 - Shetland Islands	49.40%	71.40%	40.00%	40.00%
3	ES111 - A Coruña	39.10%	57.10%	40.00%	10.00%
2	UKM64 - Western Isles	34.10%	57.10%	30.00%	10.00%
4	UKM65 – Orkney Islands	34.10%	57.10%	30.00%	10.00%
5	UKM61 - Caithness & Sutherland and Ross & Cromarty	27.10%	57.10%	20.00%	0.00%
6	PL812 - Chelmsko-zamojski	15.00%	0.00%	30.00%	0.00%
	Revised benchmark group averages	**33.20%**	**50.00%**	**31.70%**	**11.70%**

*Notes: Relative to shortlisted region mean average values. Vulnerability score composed of 10 indicators (weighted 50% of total score), Dependence 7 indicators (weighted 30% of total score) and Pandemic impact 10 indicators (weighted 20% of total score)

The statistical significance t-tests were also re-run for the revised shortlist and benchmark group. The results point towards more expected results once the sub-regions with access to better connected and seemingly more resilient airports are removed and added to the benchmark list (Table 7). The change in pandemic impact score differentials is particularly marked with the revised benchmark group only being worse off than the shortlist average 12% of the time versus a revised average shortlist sub-region score of 51%. This differential was significant at the 99% confidence level. Due to the larger amount of air transport activity, the dependence on air transport indicators were still higher in the benchmark group 50% versus 44%) but the differential on this occasion was not high enough for it to be statistically significant. The overall score differential along with the vulnerability score differential were both significant giving a strong indication that both ES111 and PL812 should not be on the highest order priority list. In examining the benchmark group further, the Shetland Islands has an overall weighted score of 49%, which would place it 7th on the revised shortlist. Aside from its high air transport dependence as a remote but moderately populated Scottish island chain, the region's main airport gateway at Kirkwall (KOI)[3] had worse indicators than the shortlisted sub-region average 40% of the time for both vulnerability and pandemic impact. It is fully dependent on one privately owned carrier (Loganair – LM), despite being government owned, the Highlands and Islands Airports company Ltd had a high gearing towards debt in 2019 (debt to equity ratio of 5.3). Loganair also had a comparatively high debt-to-equity ratio in 2019 of 4.6. On the flip side, the airport benefits already from the Scottish Government's Air Discount Scheme and also from as many as six subsidised PSO routes in 2019. Interestingly Polish region PL812, Chelmsko-Zamojski, had a lower overall V/D score than the other benchmark regions despite being on the

[3] Sumburgh airport (LSI), located south of Lerwick, is the main airport serving the Shetland Islands, but KOI is the largest airport within 200km

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original shortlist. Versus the shortlist group average its dependence on air transport is low due in part to its low tourism activity. Relative to other regions its main serving airport, RZE has been more resilient, seeing lower reductions than many of the other featured sub-regions during the pandemic period. Only three of the ten vulnerability indicators for PL812 were more vulnerable than the average shortlisted sub-region, namely being reliant on privately owned LCC Ryanair for continued connectivity and the hitherto absence of any state aid or PSO support.

Table 7: Student t-test results: revised shortlist v benchmark sub-region V/D and pandemic impact

t-Test: Two-Sample Assuming Unequal Variances- total V/D and P score (revised)		
	Shortlist (n=11)	*Benchmark (n=6)*
Mean	0.48	0.33
Variance	0.03	0.01
df	14	
t Stat	2.27*	
P(T<=t) one-tail	0.02	
t Critical one-tail	1.76	
t-Test: Two-Sample Assuming Unequal Variances - Dependence score (revised)		
	Shortlist (n=11)	*Benchmark (n=6)*
Mean	0.44	0.5
Variance	0.03	0.06
df	8	
t Stat	-0.51	
P(T<=t) one-tail	0.31	
t Critical one-tail	1.86	
t-Test: Two-Sample Assuming Unequal Variances - Vulnerability score (revised)		
	Shortlist (n=11)	*Benchmark (n=6)*
Mean	0.5	0.32
Variance	0.05	0.01
df	13	
t Stat	2.40*	
P(T<=t) one-tail	0.02	
t Critical one-tail	1.77	
t-Test: Two-Sample Assuming Unequal Variances - Pandemic impact (revised)		
	Shortlist (n=11)	*Benchmark (n=6)*
Mean	0.51	0.12
Variance	0.12	0.02
df	14	
t Stat	3.23**	
P(T<=t) one-tail	0	
t Critical one-tail	1.76	

Note: *significant at the 95% confidence level **significant at the 99% confidence level

Existing state aid and/or Public Service Obligation (PSO) related support in the shortlisted sub-regions is covered within the V/D score under the vulnerability category. Examples of state aid which have not been prevented by EU State Aid rules include the municipalities of Sundsvall and Timra annually compensating SDL airport from public funds at an amount equivalent to the operating loss of each year until end of 2023 (SE313), public financing in the year 2013 to the tune of €3.3mn in TMP for investments in access and security control systems (FI193), and €12 public sector infrastructure and expansion grants in 2010 to Finavia Oyj at Oulu

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airport (OUL – FI1D9), with Finavia Oyj itself investing €9mn.

In the absence of commercial services and in order to maintain an appropriate level of scheduled air services on routes vital for the economic development of the regions they serve (EC, 2021), Public Service Obligations (PSO) routes have been in effect for a number of the shortlisted sub-regions. These are the Caceres sub-region in Spain (ES432) with two PSO subsidised routes from Badajoz (BJZ) to Madrid (MAD) and Barcelona (BCN); the Norrbottens län sub-region (SE332) in Northern Sweden with one local PSO route operated by Jonair AB from Lulea airport (LLA) further north to Pajala airport (PJA); and a number of PSO routes amongst the benchmark Scottish sub-regions operated by Loganair in the Orkney Islands – UKM61 and Western Islands – UKM64, and Airtask in the Shetland Islands – UKM66. The purpose of these routes is mainly to operate local intra-island services with only one of the 12 PSOs awarded to these sub-regions linking with a main hub airport at Glasgow International Airport (GLA) from the small beach airport at Barra (BRR) in the Western Isles, operated by Loganair (awarded between 2015 and 2019).

From the above information it is possible to cluster the shortlisted and benchmark sub-regions into three different groups: Those sub-regions whose serving airports and air carriers have had access to some form of state aid (including airport incentives to airlines such as Ryanair) at any point from 2010 onwards and/or PSO support (in 2019), those sub-regions that have not benefitted from any recorded form of state-aid or recent PSO support and finally those sub-regions that are not currently served by any airlines or airports and where there are currently no foreseeable plans in place to create any new local commercial air access. The results of the clustering process can be observed in Figure 10.

Figure 10: Clustering of sub-regions by level of public support (state-aid/PSO/local airport)

Note: Excludes the pandemic period and any non-published/confidential regional inventive schemes. *Some early exploratory plans are in place to consider a new airport site at Lociki

Most of the shortlisted and benchmark sub-regions fall into the 'some form of public support' category. Pohjois-Karjala in Finland and Tulcea in Romania are the only two sub-regions that fall into the limited or no public support cluster whilst Latgale in Latvia is the only sub-region without any local airport/airline service offering at all within the 200km threshold.

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7. Stakeholder implications and conclusions

This study proposes a multi-step sifting framework, which stakeholders such as regional airports, air carriers, policymakers, regional authorities and central governments can use to assess levels of prioritisation for new or continued public intervention. It uses a novel application of inequality (20:20 ratio) to assess disparity of air transport connectivity both within and between European countries and regions and, as demonstrated by this research, can be used as a basis to indicatively form views on sub-regional air transport vulnerability.
The study further provides a shortlisting methodology and in-depth V/D analytical framework for stakeholders to better understand, in the presence of scarce public resources (as is the case in Europe), which sub-regions should be most deserving of prioritisation for taxpayer funded support. The study showed that underlying inequalities in access within and between European countries has developed over time and pre-pandemic was at high levels in some regions and countries, namely in Finland, Latvia, Sweden and Spain. A third layer of analysis, looking into the impact of the ongoing Covid-19 pandemic has also been added to the framework, where a deterioration of already low and unequal levels of air access are of particular interest in understanding the combined structural and temporal aspects underpinning prioritisation recommendations. The pandemic impact was found to be significant in some of the same shortlisted Finnish, Spanish and Latvian sub-regions.

Both Lagtale in southeastern Latvia (LV005) and Pohjois-Karjala in Central-west Finland (FI1D3) appear in the top 5 sub-regions for prioritisation in accordance with the statistically significant revised list (Table 6) and also in the clustering with limited or no public funding facilitating air access (Figure 9). It is therefore possible to recommend that due consideration be given to the merits of policy intervention for ensuring a baseline of essential scheduled for the large numbers of residents living in these regions. In the case of Pohjois-Karjala, there has been some inherently inconsistent seasonal traffic available from the smaller gateway of Joensuu (JOE), as well one direct service to Helsinki (HEL) but, given its residents' potentially higher propensity to travel (as shown by relative regional GDP per capita in Appendix A), the lack of recent state-aid or route level PSO support for either JOE or the slightly larger KUO airport, and its high relative V/D and pandemic impact scores, this would be the type of sub-region that would be deserving of an in-depth assessment of the types of public support that could assist both during the pandemic recovery period, but also in order to address the inherent inequalities of access that have developed within and between countries in Europe over time as highlighted in this study.

The sub-regions that have been listed as having already been subject to some form of state-aid or PSO support may also be deserving of continued public intervention and subsidisation in order to maintain a baseline level of air transport access and associated welfare benefits. It is possible that other regions featuring in the shortlist may have PSOs coming to an end or not being renewed, or that previous grants and state-aid have been focussed in the wrong areas (e.g. airfield infrastructure support as opposed to demand focussed support). It may also be possible to explore other types of intervention, including joint grants to airlines and airports for route development, tax benefits or working with local and regional tourism authorities and chambers of commerce to improve the marketing associated with new or existing air services. This work represents the natural next step to build on the shortlisting and prioritisation framework developed in this study.

There are some limitations to this research primarily in terms of data sources used. Dependency scores are generally not at the NUTS3 level and there may be unpublished or sensitive public support measures already in place within a number of sub-regions that have not been picked up by this study. The study proposes a framework, however, that can be easily re-applied with further disaggregated and therefore reliable data as and when it becomes available. The initial algorithm set the resident catchment parameter at 200km – this led in some cases to the largest airport for a particular sub-region being located further away from a smaller airport, which may also play an important, though smaller role in terms of traffic market share, for the residents living in a particular sub-region. This study also purposefully excluded seasonal charter traffic from the dataset given the fact that residents are not able to rely on these services all year round. However, for some parts of Europe, southern and Mediterranean sub-regions in particular, the important role of seasonal charter traffic for bringing in summer tourists from Northern Europe has been underestimated. The role of local and regional airports in facilitating cargo traffic into sub-regions has also not been considered.

The weightings given in the in-depth vulnerability (50%), dependency (30%) and pandemic impact (205) analysis could also be challenged. The benefit of the framework methodology used, however, is that a number of other weightings can be posited and tested to determine if they produce more realistic and appropriate outcomes. The weightings used in this study were based partly on the lack of disaggregate data availability for the dependency score. If such data becomes available an equal weighting with vulnerability should be considered. A lower 20% weighting was given for the pandemic impact as it was important not to skew the highly apparent and significant underlying disparities up to 2019 that were found in this research.

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Appendix A

NUTS3 region	2018 GDP/capita (as % of country avg; as % of EU27 avg)*	Population distribution**	Transport**	Economy and major industries**
Latgale, Latvia	47% 24%	Even distribution of population, with denser concentration around Daugavpils in the southern part.	Region can be reached by rail from Riga. Rail network also supports freight transport to neighbouring Belarus and Russia. Road accessibility is guaranteed by a good motorway and express road system in the region. The region is currently missing an airport, but there are exploratory plans to renovate local airfield of Daugavpils until 2027 so that it would serve passenger connections[1].	Local economy consists of transport and logistics companies, technical engineering industry (e.g. production of locomotive parts, high tech cabling), construction and steel works, food processing and wood industry.
Caceres, Spain	76% 65%	One of less populated areas of Spain. Most of population lives close to Caceres, in the southern part of the region. Region can be considered mostly rural. Northern parts see lower density of population.	Good network of highways provide convenient road accessibility. The high-speed train connection to Madrid is under construction with plans to launch gradually between 2023-2030[2]. Former plans to extend the link to Lisbon have been withheld.	Region is one of least advanced in the country and relies mostly on agriculture (tobacco production, cattle raising) food processing and construction[3].
Salamanca, Spain	82% 70%	Population is evenly distributed in the region, with denser concentration around the capital city of Salamanca.	Road accessibility is guaranteed by a system of three motorways intersecting in the region. Conventional rail link with Madrid is also available. The region has its airport in Salamanca, but it has been missing connections since 2015.	Salamanca is an important linguistic centre, attracting 40 000 international language students a year (worth €50 M a year[4]). There are two research centres in Salamanca: Cancer Research Centre and Institute of Neuroscience[5]. Larger companies are located in neighbouring Valladolid – e.g. growing aerospace industry, communication and information technologies,
Zamora, Spain	77% 66%	Population is concentrated mostly around two major cities – Zamora and Benavente. The remaining parts are evenly populated.	Road accessibility is provided by a rich network of 5 highways in the region. High speed train connection to Madrid is available.	Zamora region relies on its natural resources, with mining, forestry, food producing being the major sectors. Larger companies are located in neighbouring Valladolid – e.g. growing aerospace industry, communication and information technologies, automobile industry (IVECO, FASA-Renault, Michelin), Pharmaceutical industry.
A Coruna, Spain	92% 79%	Population density is visibly higher compared to other shortlisted regions of Spain. Highest concentration is visible around A Coruna and Santiago de Compostela, but it remains relatively high across the whole region.	Road system is developed mainly in the eastern part of the region, providing highway connection to Madrid and to northern and western coast of the peninsula. There is a major seaport in A Coruna. A system of high speed rail connects local cities, but is currently missing linkage to the national network (link is to be constructed by 2022[6]). There are two airports in the region, A Coruna and Santiago de Compostella, the former serving mainly domestic routes.	The region is known for its textile industry (Zara) and is a growing fashion centre[7]. Metallurgic industry is also concentrated around the seaport of A Coruna. Tourism, including religious, is an important sector for Santiago de Compostela, being the end of the St. James Way. Beyond the region, Peugeot plant in Vigo is an important employer.

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NUTS3 region	2018 GDP/capita (as % of country avg; as % of EU27 avg)*	Population distribution**	Transport**	Economy and major industries**
Gävleborgs län, Sweden	80% 123%	Highest density of population is visible in the southern part of the region, closer to Stockholm. The remaining towns are spread to the north along the coastline.	Road and rail transport system is organised along the coastline. The port of Gavle operates one of larger container terminals on the Baltic Sea[8]. The region does not have a dedicated airport. Slightly over half of population lives closer to Arlanda Airport than to Sundsvall-Timra airport.	Transport and logistics is one of major sectors in the region. Local companies also specialise in geographic information systems (ESRI, Geomatikk, Sokigo, Lantmäteriet and Metria). Like other regions of Sweden, Gavleborg County relies on its natural resources, with pulp and paper industry and forestry being other important sectors. Large media and window production are also amongst the larger employers in the locality[9].
Norrbottens län, Sweden	104% 160%	Largest cities are located close to each other in the southern part of the region. Northern and western parts consist of large, almost unpopulated lands.	Road system provides north-south connectivity, but except for the southern part, travel distances are long. Air transport is needed to communicate with the southern part of the country – there are five airports, with Lulea being the fifth largest in the country. Railway system is also available, but freight traffic prevails.	The region is reliant on the natural resources. LKAB, iron ore mining company is the largest employer, along with SSAB, a steel manufacturer. Automotive and forest industries are also important sectors. 40% of local population works in the public sector. Facebook Data Centre in Lulea is an example of IT infrastructure in the region.
Pohjois-Savo, Finland	85% 119%	Population is evenly distributed across the region. Nearly half lives in Kuopio and the surrounding area. A third of the regions' population lives in Kuopio. Other bigger towns are located on a vertical axis of the region	Major road corridor going through the centre of the region connects north and south of the country. Rail track is parallel to the road system. Kuopio airport supports domestic flights and several charter connections.	Machinery industry is important part of the economy with companies such as Ponsse (forest machinery), Normet (mining machinery), Profile Vehicles (specialty vehicles), Junttan and Hydroline (hydraulic pile driving machines). Natural resources are used by forestry and related wood processing sector, along with combustion energy plants. Kuopio region is an important water expertise centre. Milk production, and wellbeing are other branches of the region's economy[10].
Pohjois-Karjala, Finland	79% 111%	Community is distributed centrically around Joensuu, the region's capital. Nearly half of population lives in Joensuu itself.	Like other regions of Finland, road network provides north-south connectivity. Freight and passenger railway is also available. The region is served by Joensuu airport (frequent connection to Helsinki and several warm charter destinations).	Forestry is a key sector of local economy. Joensuu Science Park is an example of the region's effort to foster local information and communication technology. Other large employers in the region include Abloy- lock manufacturer, John Deere- agriculture machinery manufacturer and Medisize Corporation (part of Phillips, plastic processing)[11].
Pohjois-Pohjanmaa, Finland	82% 115%	Population concentrated close to the coastline, around Oulu. There are vast unpopulated areas in the north-eastern parts of the region	Major road is parallel to the coastline, but the remaining road system covers symmetrically the remaining part of the region. Railway is available, but only along the coastline. Considering air transport, Oulu Airport serves 1 mppa, being the second largest airport in Finland.	Major industries include metal and mechanical engineering, as well as paper and cardboard production[12]. There is increasing focus on expertise technology, with companies such as Nokia, Siemens being examples. Like other regions of Finland, the public sector is an important source of employment in the region.
Keski-Suomi, Finland	85% 119%	Southern part of the region, where the capital city of Jyvaskaala is, sees higher population density. Remaining part of the population is spread towards north along the major road of the region.	Owing to a centric location in the country, the region is characterised by relatively good rail and road infrastructure compared to other regions of Finland, with roads connecting south to the north and east to the west.	Local economy includes machinery and equipment manufacturers, construction and bioenergy companies. Valmet, a provider of machinery and expertise to pulp and paper producers.

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NUTS3 region	2018 GDP/capita (as % of country avg; as % of EU27 avg)*	Population distribution**	Transport**	Economy and major industries**
Tulcea, Romania	80% 28%	Tulcea sub-region is one of least populated in the country. Most of its population lives in Tulcea and a few neighbouring cities in the north, but it should be stressed that nearly a third of the region's area consists of the Danube Delta.	The region's transport infrastructure is of lower quality compared to most of regions in the shortlist. Tulcea region is connected to the country by road system, but of lower standards than in other countries. Also, a rail connection is available, but lengthy and circular. The region also has an airport in Tulcea, but it has not seen regular operations since 2014 .	The region is reliant on natural resources. Agriculture, fish canning, reed harvesting are important sources of income for local community. A basic metallurgic industry has also developed in the region, with shipbuilding and ship repair companies being examples. Also, an aluminium refinery is one of larger employers.
Chelmsko-zamojski, Poland	52% 22%	Population is evenly spread across the region, although the region can be considered less densely populated compared to other parts of the country Two bigger populations around Chelm and Zamosc are visible.	County itself does not have a high-speed road connection, as it ends in neighbouring regions. National roads connect cities and also provide transit route to Belarus and the Ukraine. Rail connection is available, but circular and uncompetitive to road transport.	Agriculture and food processing are major parts of local economy. Dairy industry, foresting, local cement mills and wood processing companies are other sources of employment to the local community.
Caithness, Sutherland, Ross and Cromarty, Scotland, UK	89% 95%	Large, sparsely populated northern areas of the Highland Scottish region with populations spread out through valley, loch and coastal areas.	Regional train services linking to Inverness and from there to the National rail network. One trunk road running north-south along east coast. North-western parts of region more cut-off by road (no major roads) and no rail services. No commercial scheduled services from Wick airport (WIC) nearest airport lies outside sub-region at Inverness (INV)	In Caithness and Sutherland 35% of businesses in agriculture, forestry and fishing, large public sector e.g. over 3,500 health sector employees. Food production, fishing and tourism are the main employers in Ross and Cromarty
Western Isles, Scotland, UK	85% 91%	Island community, largest settlement is Stornaway (c.5,000 at 2011 census) on Lewis and Harris island, with rest of population spread out in mainly coastal areas	Ferry services form main link between islands and mainland and between some (not all) of the islands. Micro airports at Stornaway, Barra and Benbecula provide links to trunk air services from Inverness (INV) or Glasgow (GLA)	Main industires are small scale food production, fishing and weaving (tweed). Incoming tourism is also major sector for the Outer Hebrides (Western Isles).
Orkney Islands, Scotland, UK	113% 120%	Multiple islands North of Scotland with the main island (Mainland) being home to 75% of total population (urban areas of Kirkwall and Stromness)	Kirkwall (KOI) is the main airport gateway, only providing links to other Scottish points, however (e.g. INV, GLA, EDI) for onward connections. Ferry links to Scottish mainland and other islands provided by NorthLink and Pentland ferries (approx. 2 hrs from Thurso to Stromness). Extensive local road network on Mainland island only.	Agriculture provides employment for 25% of total workforce, fertile soil. Large public sector employing 33% of total workforce, sizeable tourism and retail sectors also. Significant renewable energy resources (EMEC based there).
Shetland Islands, Scotland, UK	129% 138%	Located 170km from mainland Scotland, remote island chain. Main settlement of Lerwick, representing more than 30% of total population. Remaining population spread out across multiple islands	12 hr ferry service link from Lerwick to Aberdeen (NorthLink Ferries), some connecting at Orkney Islands (Kirkwall), adding 2 hours to the journey. Sumburgh (LSI) airport is a 30 min drive from Lerwick with direct air connections to other Scottish points only (to GLA, INV, KOI and EDI)	Main industries are food production, fishing (especially salmon), offshore renewables and oil production. Incoming tourism also an increasingly important part of the local economy but less so than other benchmark Scottish regions. 85% of business in Shetland are micro-sized (less than 10 employees)

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