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The Effect of Covid-19 On Air Traffic Passenger Volumes In Europe

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Abstract

With both the latest global pandemic and humanity's first flight taken place almost 100 years ago, the Covid-19 virus outbreak of 2020 came to be in a very different world. The now well-developed global passenger transportation system was among the most effected by the pandemic as it experienced one of the largest declines in history. This thesis aims to identify and study the negative effect the Covid-19 pandemic has had on passenger air travel in Europe during the year 2020. More importantly, we will focus our discussion on isolating the mechanism or the probable cause behind the decline in air travel. We use an FE design to investigate how passenger volumes in each European country correlate with Covid-19 metrics that indicate the severity of the pandemic (cases & excess mortality). This study fails in finding evidence of a causal relationship between the degree of Covid-19 spread and passenger flights volumes. The results were unintuitive positive coefficients meaning more passengers flying to countries the more effected they are. Thus, we propose that government-imposed restrictions were the most likely drivers behind the decline in passenger volumes and not Covid-19 metrics. It may be unlikely that potential passengers in Europe were examining Covid-19 data before deciding which country to fly to but instead adhered to government regulations prohibiting or advising against flying.

Keywords: Covid-19, Air travel, Europe, Global Pandemic

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1. Introduction

When Covid-19 started spreading in Europe in the beginning of the year 2020, our society witnessed several sudden and drastic changes. A number of these changes were completely new for most as Europe or the world has not been in a crisis like the pandemic of 2020 since the second world war. One of these shifts, aside from the numerous pandemic related events, is the sharp decline of air travel in Europe. Passenger flights in 2020 were historically much fewer in numbers and if planes flew, they carried few passengers, flying sometimes no more than a dozen people. Furthermore, the decline in air travel in Europe was not uniform across the continent and there were differences in flight activity between countries. The general cause of this decline may be obvious, but the specific cause is less certain. For carriers and air travel companies, it is vital to know exactly how their industry was affected by Covid-19 as this information will be of use when planning current and future routes. This rare global occurrence, while still damaging, presents an opportunity for learning that can strengthen the resilience of the industry in the face of a potential future crisis. Therefore, airlines and other industry stakeholder should attempt to answer the question: why did people stop flying?

Motivated by the current events of 2020, we attempt in this paper to study air travel activity in Europe during the pandemic to determine the reason behind the decline of air travel. First, we hypothesized that passengers were the decisionmakers who made a choice of “travel” or “not travel” by air in Europe. Furthermore, this choice was influenced by the Covid-19 situation in a specific country. That is, if there were less cases in country B compared to country A, passengers would make, based on a rational evaluation, an active and independent decision to travel to country B where there are fewer cases than country A. However, after multiple regressions using monthly data on passenger air traffic and Covid-19 in Europe during the pandemic, we came to illogical results as there seemed to be more air travel activity in a country, the more Covid-19 cases it had. This goes against the hypothesis of consumers being the decision makers and signals the existence of another factor at play which affected flights more than the direct lack of demand from individuals.

Eventually, we arrive to the conclusion that this factor is the pandemic related measurements enforced by the different governments in our data sample. Basically, the leadership of the various European countries were the decision makers that drafted a series of instructions to their citizens which had a profound negative affect on air travel. The instructions were either direct by closing borders and airports, or indirect by communicating to the population that air travel is currently not recommended. Surly, some passengers made the decisions themselves by studying the spread of the virus and opting to travel to countries that are less affected. But still, the restrictive measurements imposed by the governments of Europe is the best explanation to why people stopped flying in the continent.

We present more reasons for why the imposed restrictions might be the most important reason behind the drop in air travel. Apparently, the sharp decline in passengers carried correlates with the announcement of the different measures imposed by the relevant governments. Data on the degree of travel restrictiveness and the passenger volumes carried confirms this. If there was a lockdown imposed in a country, the inhabitants of said country would simply avoid traveling in accordance with the instructions given. We find that even if airports remained open, a clear majority of the population chose to follow the recommendations of avoiding travel. Passengers were thus not looking at Covid-19 charts when deciding where to fly but instead looked up to their respective governments for advice and guidance. Thus, if airlines wish to be more dynamic during the pandemic with flight planning, more attention should be directed towards the policy implemented by the states. Airlines would be misguided if they plan more flights to countries less affected by Covid-19 but with stricter measures as people will mostly only fly if their governments allow or not discourage it.

2. Background and literature review

In this section we will discuss the onset of the global Covid-19 pandemic, individual mobility and the spread of diseases, and the role of travel and air travel in the current pandemic.

2.1 The Covid-19 pandemic

Coronavirus is a well-known family of viruses that first surfaced in North America in the 1920s among domesticated chickens and was later studied in 1931 by Arthur Schalk and M.C. Hawn (Fabricant, 1998). subsequently, the Virus was isolated in 1933 and cultivated for the first time in 1937. Several other strains were discovered, each infecting a specific species. For example, in the late 1940s JHM which causes brain disease and MHV or mouse hepatitis virus that causes hepatitis among mice were discovered (Decaro, 2011). It wasn't until the 1960s that the first coronavirus was discovered in humans and subsequently isolated in 1962. Virologists at that time cultivated the virus using kidney tissue culture and were now able to relate it to the coronavirus family first discovered in mice (Hamre, 1966). Since the 1960s several other human coronavirus strains were discovered as well as an even larger number of animal coronavirus (Groot, 2012). These include *SARS-CoV* in 2003, *HcoV HKU1* in 2004, *MERS-CoV* in 2013 and most recently, *SARS-CoV-2* in 2019 or the corona virus of the 2020 global pandemic.

In December 2019 several patients with symptoms including cough, fever, fatigue, breathing difficulties and loss of smell and taste were reported in hospitals across Wuhan, Hubei, China. After a period, several medical officers flagged the disease causing these symptoms as novel and highly contagious. The government received these reports on 27th of December 2019 and published them on 31st December 2019. On 8th of January 2020, Chinese scientists identified the cause of the pneumonia as a disease caused by severe acute respiratory syndrome Coronavirus 2 or what is clinically known as *SARs-Cov-2*. The new disease was given the designation Covid-19 by the WHO several weeks later (WHO, 2020). The exact origin of the virus is not yet clear and is currently a debated and studied subject. A member of the United States senate suggested that the virus came from a virology lab in Wuhan (Pengelley, 2020). However, most virologists argued for a natural explanation with animal-human transmission (Xingyi, 2015). Although studies are still in progress, the consensus is that the virus is relatively much more contagious but also less deadly than the *SARS-CoV* virus that also spread in China back in 2003. This claim, however, as is the case with many of the claims circling Covid-19, is still under thorough scrutiny and in need of more data to be validated.

During the first weeks of 2020 after the virus was designated, Covid-19 spread exponentially as the infection rate was firstly underestimated by the Chinese authorities. Lockdown and other stringent measures introduced on the 23rd of January to keep the virus in Wuhan were only partially effective as they slowed the infection but failed to contain it. The suppression of the viral proliferation was not easy since the large city of Wuhan is an important travel hub for Chinese citizens returning from the new year festivities. As a result, the virus was detected in every province in mainland China by the 29th of January (WHO, 2020). Covid-19 was temporarily dormant after contagion and symptoms were not visible only after approximately five days or up to two weeks. Consequently, many infected and unaware individuals boarded international flights and spread the virus outside of China. The first country reporting Covid-19 cases outside mainland China was Vietnam on the 24th of January followed by several Asian counties such as Japan, South Korea, Nepal and Thailand (WHO, 2020).

On the same day, France reported its first three imported cases marking the arrival of Covid-19 to Europe. While also still a debated and researched subjected, the virus was said to have been spread at ski resorts in the Italian/French Alps where several businesspeople were enjoying the holidays in early January. Several of these may have been to China on business trips where they had contact with someone carrying the virus. Regardless of how the virus came to Europe, northern Italy and Germany reported their cases three or four days after France (Böhmer, 2020).

Thus, the virus spread further into continental Europe with daily Covid-19 cases increasing multiple folds in the hardest hit areas. As a result, more reliable and accurate data on the contagiousness, symptoms and lethality of the virus was made available to the leadership of the European countries and the rest of the world. Responding to this, several countries initiated multiple procedures with the aim of containing or at least mitigating the spread of Covid-19. The containment procedures started much earlier when several nations halted all flights to Wuhan and eventually China. However, with the first cases appearing in mainland Europe decisions were made to halt all international flights entering or exiting affected areas. Moreover, some European countries expanded the flight ban to also include regional and domestic flights as well. Countries which did not stop flights advised strongly against any unnecessary travel using airplanes or any other transportation method. The containment procedures were gradually expanded but still varied across countries ranging from total lockdown to awareness campaigns communicating the importance of avoiding crowded and enclosed spaces for example on trains or busses (Deutsche Welle, 2020).

2.2 Air travel and virality of contagious diseases

Air travel is unmistakably a major contributor to the spread of disease vectors. It is currently the only mean of common transportation that can transport a virus to any place on the globe in less than 24 hours. This increases the risk of potentially infected passengers carrying the virus across the world well before any symptoms are felt or observed. Travelling by air also includes using airports where a dense quantity of people is physically interacting and then flying to a variety of different destinations. A single international airport usually services hundreds of international or domestic flights every day carrying hundreds of passengers to almost every country on the globe (Ikonen, 2018). Airplanes also need to be more fuel-efficient than for example trains or cars, so passengers are packed more tightly on a plane which further increases the risk of contagion. Furthermore, airplanes recirculate around 50% of the air inside the cabin after reaching cruising altitude. This air is passed through special HEPA filters that effectively sterilize it, but the filters are not always required to be used on airplanes by the relevant aviation authorities, for example the FAA in the US (Day, 2015). This is unlike other means of transportation where air is channeled from the outside and is completely sterile. Thus, the lack of filters can expedite the spread of the disease inside the cabin, increasing the number of virus vectors during the trip itself and further contributing to the spread. additionally, contagion can happen in other ways especially if the virus is relatively heavy and does not travel far by air, as is the case with Covid-19. During a flight the passengers share several amenities that can be a hotspot for contagion. A couple of toilettes on a passenger airplane for example can be used by hundreds of passengers and if not sterilized will contribute to the spread of the contagious disease (Pavia, 2007). Air travel is thus an important factor in global pandemics because of its ability to transport pathogens great distances in a short period of time during which the survivability of the pathogen is more likely compared to other transportation methods. In essence, the air travel infrastructure and ways of conduct facilitates a very favorable environment for the spread of the virus to more hosts or surfaces.

Mangili et al. (2005) studied how passenger air transportation can improve the conditions for the transfer and spread of diseases and pathogens. The study identifies that the risk of transmission within the confined space of a plane cabin is difficult to determine due to insufficient data. However, the study states that insufficient or inadequate ventilation can increase the risk of transmission for airborne diseases and the confined space in turn makes contact transmission more likely. The paper concludes that commercial airlines are a suitable environment for the spread of any pathogens carried by the crew or passengers. Still, the perceived risk may still be higher than the actual risk as measurement and policies made by both airlines and airplane manufacturers have improved the cabin environment. For example, HEPA filters or “High Efficiency Particulate Air” filters are being used on an increasing number of airplanes. It is important to note that this study only examines how well a disease can spread inside a plane and does not consider what effect the transportation itself has on the overall spread of the disease geographically.

Air travel is also a new component in the global spread of pathogens. During historic global pandemics like the Spanish-flu in the early 1900s, it took days if not weeks by rail or sea ways for an infected passenger to travel cross continents. It was also generally much more expensive to travel during that time compared with today (Willis, 2015). As a result, most people did not have the opportunity to travel large distances. However, with the invention of the airplane and the subsequent improvement of this invention, travel costs have been greatly reduced. Thus, travelling long distances has become attainable for larger portion of the world population. The reduced costs and the improvement in the air travel infrastructure has increased the total volume of passengers traveling by airplane to a record level and if the Covid-19 pandemic had not occurred, the trend would most likely have continued. In 2019 for example, 4.5 billion passengers were carried by airplanes which represents an increase of 4.2% compared to the year before. Demand has often, until recently, outpaced supply which has guided investments into making air travel more fuel efficient. For example, aircraft manufacturers like Boeing or Airbus are constantly seeking to develop planes that fly further and carry more people. Airports are not only increasing in numbers but also in size, as large investments in airport infrastructure have increased the global carrying capacity of passengers (Mazareanu, 2020). This naturally translates into clusters of dens populations going to and coming from thousands of different destinations. These factors can in part explain why a virus is able to spread faster and more globally than historically was possible. In fact, the global air travel system has become so complex that mapping how the virus spread from Wuhan during its first stages is very difficult to model (Hanson, 2020).

One of the reasons why the developed world cannot properly function without flying even when considering the risks mentioned, is the obvious benefit this transportation method provides. Essentially, air travel is vital for the global economy. Not only because it is an industry with an estimated worth of 3.5 trillion dollars, but also because of the indirect benefits that the global air travel has on business connectivity. Campante & Yanagizawa-Drott (2017) researched the effect of air links on global GDP through the positive effect the increased connectivity has on capital movement. They show in their paper how an increase in air links leads to an increase in business links and in turn economic activity. According to the authors, more people travelling fosters an increase in the movement of capital and ideas which subsequently leads to increases in productivity, innovation and in turn GDP. The global flight network has thus transformed the global economy and is now a vital ingredient in it. Therefore, a sudden and unexpected disruption can have major consequences not only on the aviation industry but the entire world economy. It is therefore important to study this relativity young and fast-growing industry that has become an integral part in achieving economic stability. Especially if air travel plays a lesser role in spreading pathogens after it already entered a country or even spread globally.

The global air travel network is thus deemed as a crucial component in the fast-paced development of the global pandemic. It didn't come as a surprise then when the governments of several countries around the world opted for complete travel bans, not recommending traveling to affected areas or discouraging traveling at all. Therefore, the relation between the spread of Covid-19 and the relevant passenger flight activity is an interesting topic to study considering the recent pandemic.

2.3 Air travel and Covid-19

Before we start with this section, we want to state that Covid-19 is not only a very recent phenomenon but is also an ongoing one. Therefore, the research on the subject is still in development and the literature presented is yet to be thoroughly peer reviewed and may become irrelevant once new and more reliable or accurate data has surfaced. Nevertheless, we have been able to come by a sizable volume of early research on the pandemic and air travel, most of which was published in the year 2020.

S.M. Iacus, et al. (2020) have attempted with their research to not only estimate the impact of Covid-19 on global passenger traffic but also estimate the effect of this decrease on the world's GDP. Firstly, the study uses a forecasting model that builds on historic data and adjusts for non-linear trends and cycles which are specific to each studied flight route. The forecasting model allows the researchers to roughly estimate flight volumes as if no disruption has occurred in 2020, this forecast is then designated accordingly as the "baseline" scenario. The baseline scenario is the counterfactual which represents the world as if Covid-19 never spread or happened. In other words, what could have been. The paper continues by comparing the baseline scenario with several other scenarios that vary according to how well the aviation industry could recover and other historic shocks to passenger flight traffic such as SARS-2003 and MERS-2015. The aggregate data is then used to infer the drop in incremental airline revenues and thus the effect on global GDP. However, S.M. Iacus, et al. (2020) aim is much broader and ambitious than our research question as they already presume a causal relationship between Covid-19 and the subsequent decline in passenger flight traffic. Their paper uses a forecasted baseline scenario and compares it with the observed scenario. Since not all the reduction in flight volumes is linked directly to the spread of Covid-19 there might be some negative bias in their results. For instance, passenger flight volumes might have experienced a drop in 2020 outside of the forecasting model due to increased climate change awareness, improvement in digitizing communication or other macro factors specific only to the year 2020. However, the assumptions regarding the forecasting model and its ability to provide a "control" scenario where Covid-19 did not occur are still sound. Furthermore, while the estimates of the GDP loss due to the decline in air traffic is viable, it may be underestimated. As mentioned, Campante & Yanagizawa-Drott (2017) show that air travel contributes with indirect benefits to the global economy which are not captured by the industry's nominal worth.

In another recent study, Monmousseau, et al. (2020) attempted to better understand how the virus affects passenger flights after countries enforce lockdowns or subsequently travel restrictions. The paper recommends a passenger-centric approach to avoid the issue of the empty “ghost” flights that are still flown by some airlines in fear of losing air slots or a reduction in the financial assistance they receive. However, the article was written relatively early during the pandemic and traditional data was provided by the BTS (bureau of transportation statistics) with a two-month latency. Thus, the researchers used non-traditional data to map passengers flight activities using for example social media, Bluetooth beacons and Wi-Fi connectivity at airports. The issue of empty flights is solved by using data on passengers boarded or transported and avoiding using data on flight volumes. This is a crucial point as there have been many empty or near empty flights not only in Europe but across the world as airlines struggle to keep their regular flying activity unchanged in fear of losing landing slots at respective airports.

Although the following paper did not study Covid-19, we judge it to be reasonably contemporary as it discusses some pathogens that appeared since the 2000’s. Findlater & Isaac (2018) studied the contribution of air travel and the improvement in human mobility to pandemics. Their study refers to several events where the spread of a disease was expedited by air travel. For example, how the largest Ebola virus disease (EVD) epidemic began in Sierra Leone in 2014 and spread via land routes to neighboring countries and then much further from the source via international air travel. Another case which is often used to familiarize Covid-19 is the SARS outbreak that happened between 2002 and 2003 in China. The pathogen spread via passenger air traffic to Hong Kong, Canada, Singapore and Vietnam among other countries. The study suggests that air travel makes the spread of the disease to countries farther away from the source more likely and much faster than contagion via land to only neighboring countries. Furthermore, the paper adds that air travel presents a serious challenge for public health responses in isolating and mitigating the spread of a pathogen that could lead to a global pandemic. The authors recommend early warning systems, systematic screening and improved surveillance to get ahead of the pathogen and stop it before going viral. Surprisingly, they additionally claim that travel bans, and travel restrictions do not assist in containing the disease and can even worsen the situation of the affected countries. They base this claim on several earlier studies that showed how isolating developing countries can be damaging. For example, a travel ban can lead to an increased economic burden that adds on the already present cost of the outbreak itself. Logistical support to affected countries also becomes more difficult after travel restrictions are issued. This recommendation was largely not employed by the European countries during the Covid-19 pandemic except for a few nations like Sweden who chose to keep their borders open during the Covid-19 pandemic. Most European countries opted for border closures or at least discouraging unnecessary travel.

3. Methodology

3.1 Data attainment and characteristics

This paper attempts, using a FE design, to derive a possible causality between the spread of Covid-19 in Europe and the eventual change in passenger flight traffic volumes. S.M. Iacus, et al. (2020) used data from several different sources in order to ascertain the volume of flights on a global scale. On the other hand, due to the smaller scope of this paper, we will restrict our sample to Europe by using panel data from the EU: s Eurostat outlet. The service provided by the European commission makes available data on all commercial European flights and can be broken down using several categories. In order to accurately measure the flight traffic, we use data on passenger volumes instead of flight volumes. This is due to the reports of many near-empty or empty flights during the pandemic to fill certain airport quotas. Thus, using passenger volumes may provide a less biased estimate on how movement of people using airplanes was affected by Covid-19. We also note that since data on private flights is more difficult to obtain it will not be included in the data set. Moreover, we presume that such flights carry very few people in proportion to the quantities carried by standard airlines so not including these will have a miniscule effect on the result itself.

The units used in our data are volumes of passengers in numbers and these will be on a per capita (thousands) basis. The time frame is the period from January to September during the year 2020. Also, the data is constructed on a monthly basis, so each month is one-time unit. Using days or weeks instead may not provide any incremental benefit to the regression although during some periods, especially mars, data on both passenger volumes and Covid-19 was changing almost daily. The reason is that there is still sufficient variation in the data if observed monthly instead of weekly or daily. The countries used in the data sample are 33 European countries including EEA and EU members as well as nonmembers. The countries in the data set are the following: *Denmark, Germany, Belgium, Bulgaria, Czechia, Estonia, Ireland, Greece, Spain, France, Croatia, Italy, Cyprus, Latvia, Lithuania, Luxembourg, Hungary, Malta, Netherlands, Austria, Poland, Portugal, Romania, Slovenia, Slovakia, Finland, Sweden, United, Kingdom, Iceland, Norway, Switzerland, North Macedonia and Serbia.*

Additionally, data on passenger volumes during the pandemic, or the dependent variable will only include passengers flying from, to or within European countries. Therefore, Passengers arriving from a non-European country but landing in a European country are included. However, Passengers who are transiting in a European country and did not stay in the country for more than the purpose of changing flights are not included. The goal is to gather data on passenger activity going and coming from airports across the European continent. What is also not included is obviously data on passengers flying over European airspace and passengers on cargo flights as these sometimes carry some people and crew that go through nonstandard channels. We assume that the volumes of passengers flying on cargo planes that have been, for some reason, included in the data without our knowledge are so small that their effect should be negligible. The purpose of these restrictions on the flight origin and destinations in the data is to minimize the effect of other policies made by countries that are not European on passenger volumes.

3.2 Data on the explanatory variables

The other section of the data aside from passenger volumes is on the explanatory variables which are measurement of the burden of the disease. These include the number of infections and data on excess mortality caused by the virus. This data is gathered from the European Centre for Disease Prevention and Control. The center provides accurate global and European data on infection rates and testing (ECDC, 2020). This is probably the most difficult point to be certain of as data on Covid-19 is occasionally inconsistent. Firstly, the data is aggregated from a variety of outlets that differ in more than one way in their consistency and methodology with regard to collecting, measuring and communicating data on Covid-19. the European Centre for Disease Prevention and Control gathers data from among several others, the WHO, national health institutions, agencies and governments. For example, data on Covid-19 infections and excess mortality in the Netherlands is provided by the National Institute for Health and Environment of the Netherlands. Therefore, the procedures applied with which the data was collected including testing methods and volumes, measurement policy and overall reliability differs from country to country.

For example, the Swedish leadership went for less testing per capita than the UK so Sweden will have statistically, but not realistically, a lower infection rate compared to the UK (ECDC, 2020). It is not only the number of tests that can be an issue but also the types of tests as different methods of testing have a different degree of accuracy. For instance, clinical testing in labs is more accurate than other rapid testing methods (John Hopkins, 2020). There has also been a difference between countries' health institutions guidelines on when tests should be sought by people. While some countries encouraged testing for everyone with light symptoms, the Swedish public health care service communicated that a test is needed only if there are clear and present symptoms (Public health agency of Sweden, 2020). Basically, the number of tests performed per capita will directly correlate to the number of infections per capita as more testing translates to more infections. The data on infection rate will therefore challenge the accuracy of our regressions as there are large disparities between countries. As a result, if we use the data on infection rates there might be some bias observed in our results.

3.3 Excess mortality

To mitigate the possible bias mentioned above we decided to include a secondary data type. This will be the excess mortality rate due to Covid-19 which is utilized in a secondary fixed effect regression. The primary results using the infections rate will subsequently be compared with the secondary results and any difference will be evaluated and discussed accordingly. The logic behind this decision is that excess mortality is more easily and reliably measured than infection rates. Thus, using death rate as an additional data source may provide less bias stemming from the difference in testing schemes across Europe. The excess mortality rate data is gathered from EUROMOMO which is a European monitoring activity that detects and measures, in real time, excess mortality caused by seasonal influenza or any other health threats. Since our sample is restricted to Europe, using EUROMOMO provides arguably more accurate and reliable data on the excess mortality rates from Covid-19 across European countries.

Using excess mortality and not Covid-related deaths should produce less biased estimates. This is because how deaths related to Covid-19 have experienced some discrepancies in measurement and reporting. It is not always clear which requirements must apply for a death to be Covid-19 related. Several patients, mostly elderly and individuals with pre-conditions, may have experienced a deteriorating health situation even before their eventual infection. For example, a person with heart disease or terminal cancer is at greater risk of passing due to these conditions compared to Covid-19.

It's true that several patients' health may have deteriorated much faster because of their infection with the virus but claiming what was the definitive cause of death is a subjective issue. Excess mortality is the measurement of the difference in the number of observed deaths during a specific time period and the numbers of expected deaths of a previous year, or the average number of previous years (CDC, 2020). Clearly, this estimate produces more accurate and realistic data on Covid-19 mortality rates compared to using Covid-related deaths.

Another reason speaking for the use of excess mortality data is potential data manipulation, which is not very likely but still possible. During the pandemic there could have been attempts to influence the data to bring Covid-19 cases either up or down to achieve certain political goals. While this was most prevalent in countries outside of Europe like Russia and China there were unconfirmed reports of it happening in several European countries (BBC, 2020). In Italy for example, and especially during the first stages of the pandemic when the country was hit the hardest, there has been a flagging of underreporting Covid-19 related deaths and stating pre-conditions as the main cause of death (WSJ, 2020). Using excess mortality will therefore assure that any data manipulation will only influence the results through the observed deaths. And for this we assume that the likelihood of such occurrences is unlikely in a European country with low corruption index. An additional advantage is how excess mortality unlike Covid-19 cases is less affected by different testing policy choices adopted by the different countries and is thus more comparable across countries.

3.4 Statistical method

Panel data is multi-dimensional data that includes multiple measurements over time. For example, time series or cross-sectional data are basically panel data with a single dimension. The panel data used in this paper will observe not only different panel members or individual data points among the panel but will do so over time as well. Thus, the panel data used will allow between country comparisons as well as temporal comparisons. Furthermore, the regressions performed will not be pooled OLS but fixed effect regressions where we cluster the countries in the data into groups. We strongly suspect that the unobserved heterogeneity (country heterogeneity in this case) will not have a zero covariance with the independent variable and thus by definition of the pooled OLS equation the independent variable will not have a covariance of zero with the error term. Thus, the OLS estimator will be inconsistent and bias. If the unobserved effects are time-invariant, then a first-differenced estimator could potentially provide a consistent coefficient as the unobserved heterogeneity is canceled out. An assumption for a consistent FD estimator is the lack of correlation between the independent variable and the error term which does not include the unobserved heterogeneity now as these were canceled out. Although it can be hard to argue that the country fixed effects are time invariant in some cases but not in this case given the relatively short period of time between observations and the total length of period studied which is under a year.

The fixed effects estimator will yield the same result as the FD estimator if T=2. But as that is not the case here, both will be consistent, but FD will be more efficient than FE if the independent variables are strictly exogenous, meaning that there is no serial correlation in the error term: the distribution of the error term is not dependent on either its past or future.

Another option to the fixed effects model is the random effects model. Assuming that the covariance between the country specific intercepts α_i and the independent variable is zero then both these models will yield consistent estimators, but the random effects model will yield a more efficient one. If this assumption does not hold however then the fixed effects estimator will be the only consistent estimator and is therefore optimal. The Hausman test compares the two estimates and helps determine whether the random effects estimator is consistent or not and therefore if its preferable to the fixed effects estimator. The null hypothesis is that the covariance between α_i and the independent variable is zero where the test statistic follows a chi-squared distribution. The higher value the test statistic has the lower possibility that the difference is due to pure chance and we can reject null hypothesis that the covariance is zero and thus the fixed effects model is therefore preferred. Although the result from the conducted Hausman test on our last specification meant that we cannot reject the null hypothesis that the difference between the two estimators obtained under the two different models is not systematic, the fixed effects model is still the preferred model given our assumptions. Yet, all regressions will also be conducted under the random effects model and included in this paper to show that the model choice does not make a great difference in this case given the results.

In addition to the base regression, different specifications of the model will be investigated. Although Covid-19's fatality rate has been steady and thus auto correlates with the reported cases, it is possible that fatalities have a bigger impact in scaring away travelers rather than the number of cases. Furthermore, this metric is more comparable across countries as excess mortality is less affected by different policy choices with regard to testing. Regression 2 uses Covid-19 excess mortality as the independent variable in order to investigate this. An alternative specification where the timing of the effects is changed will be included as it is expected that the independent variable will affect travel decisions during the current and coming month. Regression 3 uses a lagged independent variable by one month and could give insight into whether it is affecting future travel plans instead.

Thus, the statistical method used is a Two-way fixed effects regression using the following dependent and independent variables from the panel data which are:

1) Number of passengers flown in each country during a given month. (per capita)
2) The number of reported cases of Covid-19 in each country during a given month. (per capita)
3) The number of reported excess mortality due to Covid-19 in each country during a given month.
4) The number of reported cases of Covid-19 in each country during the previous month. (per capita)

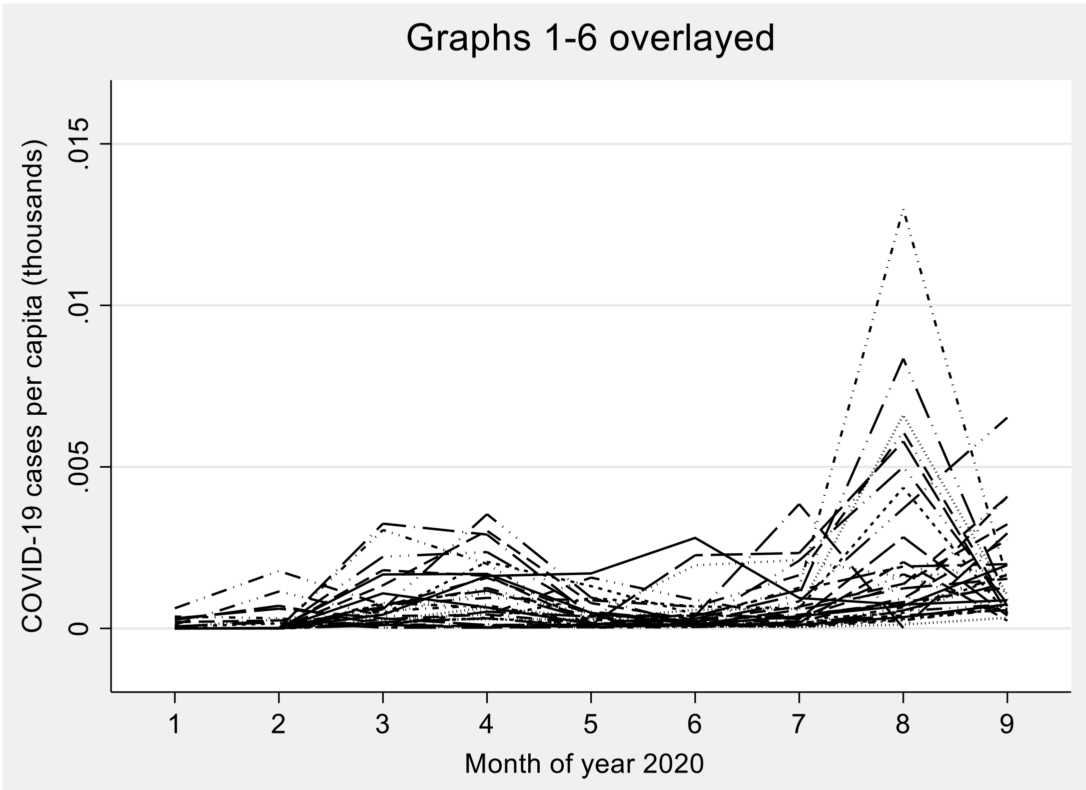
The regression model is thus:

$$\boldsymbol{Y_{it} = \beta X_{it} + \alpha_i + T_t + u_{it}} \qquad (3.1)$$

Where our dependent variable is *volume of passengers* and our independent variable is *number of reported positive COVID-19 cases*, α_i is the unobserved intercept for each country and T_t are the time dummy variables. Both the independent and dependent variables are expressed in per-capita terms (thousands).

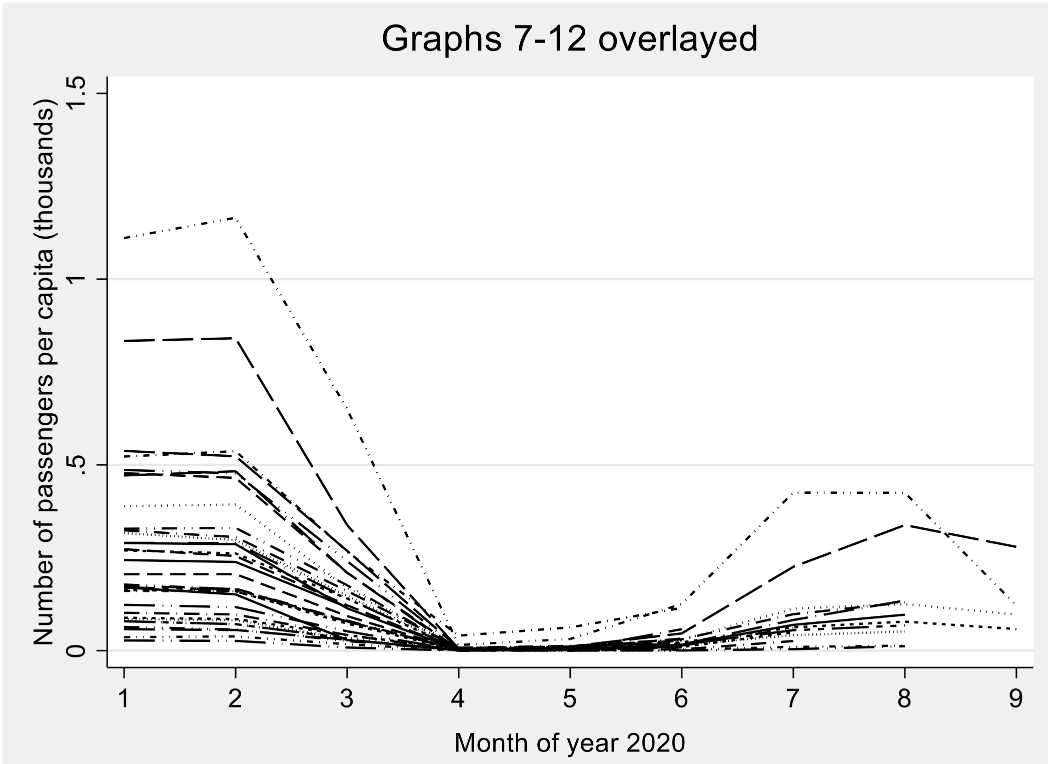
4. Results

Figure 1: COVID-19 cases per capita (thousands) I Europe during 2020



Note: Overlaying graphs 1-6 from the appendix where each line represents for each country the number of reported COVID-19 cases for each month of the year 2020 up to the 9th month of the same year. Notice the two waves experienced by most countries in the spring and in the summer.

Figure 2: Number of passengers carried (thousands) in Europe during 2020



Note: Overlaying graphs 7-12 from the appendix where each line represents for each country the number passengers carried by a passenger airplane in Europe for each month of the year 2020 up to the 9th month of the same year. Notice the sudden drop in occurring from February to April and the slight recovery starting from June.

The results of the regression were counterintuitive as all three produced positives estimates indicating a positive correlation. The summary of these are presented below.

Regression 1 yields a highly insignificant estimator of 0,422212. Meaning that there is no impact but if we were to treat it is as a significant estimator then it would mean that for each per capita reported COVID-19 case in a country during a given month the number of passengers flying within that country increases with 0,422212 per capita passengers.

Regression 2 uses per capita COVID-19 excess mortality as independent variable and yields a highly insignificant estimator of 97,11228. Meaning that there is no impact but if we were to treat it is as a significant estimator then it would mean that for each per-capita COVID-19 excess mortality, the number of passengers flying within that country during any given month increases with 97,11228 per capita passengers.

Regression 3 uses a one-month lagged independent variable and yields a significant estimator of 15,94884 at the 5% level. Meaning that if we were to accept it as a significant estimator at this level then it would mean that for each per-capita reported COVID-19 case during the previous month, the number of passengers flying within that country during the current month increases with 15,94884 per capita passengers.

Regression results under the random effects model:

The random effects model also produces highly insignificant estimators for the first two regressions and confirms that there is no impact under this model either. The third regression estimator is close to the estimator obtained under the fixed effects model in terms of magnitude and significance.

Figure 3: Output from the three performed regressions under the fixed effects model

	(1) NumPKpc	(2) NumPKpc	(3) NumPKpc
COV-19cases	0.422 (0.06)		
COV-19fata~s		97.11 (0.63)	
LaggedCOV-~s			15.95* (2.28)
N	213	213	213

t statistics in parentheses
* p<0.05, ** p<0.01, *** p<0.001

Note: Column (1), (2) and (3) show a positive correlation between the independent and the depended variables. Passenger air volumes increases the more Covid-19 cases a country has. The same effect is observed with the excess mortality variable. The lagged variable (3) still produces positive estimates

Test 1: The Hausman test

	Coefficients (b) random	Coefficients (B) fixed	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
lagCOVIDcKpc	15.47793	15.94884	-.4709133	1.926939
Time				
2	-.0113309	-.0115811	.0002502	.0092947
3	-.1592219	-.1596134	.0003915	.009376
4	-.2843904	-.2903718	.0059815	.009305
5	-.2718539	-.273819	.0019651	.0093378
6	-.2593893	-.2615179	.0021286	.0094155
7	-.2229373	-.2271307	.0041934	.0120428
8	-.172651	-.1788712	.0062202	.0124174
9	-.2327451	-.2600793	.0273342	.0187381

b = consistent under Ho and Ha; obtained from xtreg
B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

chi2(9) = (b-B)'[(V_b-V_B)^(-1)](b-B)
= 3.16
Prob>chi2 = 0.9576

Note: The result mean that the stated null hypothesis cannot be rejected and RE model is preferable. Conducted only on the last specification where we found significance (lagged variable).

Figure 4: Output from the three performed regressions under the random effects model

	(1) NumPKpc	(2) NumPKpc	(3) NumPKpc
COV-19cases	0.136		
	(7.842)		
COV-19fata~s		42.53	
		(155.1)	
LaggedCOV-~s			15.48*
			(7.267)
N	213	213	213
adj. R-sq			

Standard errors in parentheses
* p<0.05, ** p<0.01, *** p<0.001

Note: Positive correlation under the RE model as well. Column (3) estimator is very similar to the one obtained under the FE model.

5. Discussion

5.1 Unexpected results

The results from both models show that the neither the number of Covid-19 cases nor the excess mortality had a statistically significant effect on the volumes of air passengers in Europe, and if anything, based on the estimated positive coefficients, rather predicted that the number of flights goes up with infection rates (if estimator were to be treated as significant). Using the one month lagged Covid-19 as a dependent variable yielded a significant estimator at an acceptable level under both models, the wrong direction however makes for an illogical interpretation: the higher the number of cases per capita was the month before in a certain country the more air travel will increase during the current month in that country. Therefore, we do not conclude that there was an impact under this specification either as a graphical analysis of graphs 7-13. This result was not predicted and at first glance seems unreasonable. One would expect travelers to adjust their travel plans based on the severity of the pandemic situation both in their home country and the destination country. Naturally, a large part of the populace will completely refrain from traveling independently of the pandemic situation in each country, but it was expected that at least part of the populace will choose to execute their travel plans if they deem it safe to do so, this is not what the results show.

From the overlayed graphs, one can observe how the number of passengers started dropping slowly starting late January followed by a sharp decline during February when the number of cases started increasing in almost all countries. However, this decline in number of passengers is observed in countries and during months with relatively few cases, Poland and Slovenia are two interesting examples. In theory, the country with most cases during a specific month should see the greatest decline of air passengers as travelers planning to travel to said country will most likely either choose another destination or postpone their travel due to the increased risk of getting infected. With similar reasoning, the said country's populace will also abstain from traveling as they will most likely not be welcome to other countries and/or even be barred from traveling at all. However, this paper finds that not to hold but rather finds that most travelers abstained from traveling during the beginning of the outbreak irrelative of how many cases were detected in their home country or the destination country.

5.2 Escaping Covid-19 areas?

A different reaction to the pandemic could have been selective travel where we would see decreased passenger volumes to and from countries with high infection rates and a smaller decrease (or even an increase) in passenger traffic to and from countries with lower infection rates. Although the data on Covid-19 cases varies across time and countries, making this reaction plausible as the pandemic did not take over Europe at once, the drop in passengers is too uniform and steep across countries, meaning that this is clearly not what happened. Instead, we see an almost coordinated decline in passenger volume in all countries with the rise of cases in most.

Two types of travelers will ultimately affect the dependent variable: Number of travelers that have a flight booked in advance and are now facing the decision of cancelling or flying and the number of travelers that have no flights booked but want or need to travel and thus face a decision to either wait or book. The question of how a traveler can decide whether to travel or not during a certain month based on a parameter compiled at the end of that month is problematic. A solution could have been using a lagged independent variable thus making the information on the number of cases from the current month as if it were available to the traveler just before the next month begins. However, as seen in regression 3, this specification also results in a highly insignificant and counter-intuitive estimate for the coefficient in interest. The reason for this is yet clear and can be again found in the graphs: the decline in air travel happened in the same month as the increase of Covid-19 cases, meaning that travelers were most likely taking decisions based on daily information and were acting fast. So fast in fact that future studies hoping to pinpoint the reason behind these decisions will probably need weekly or even daily passenger data.

The plausible theory that it was rather the excess mortality behind the decline rather than confirmed cases is certainly plausible as death is scarier than sickness. It was with this motivation in mind that regression 2 was run. However, given the relatively stable fatality rate of the Covid-19 virus, the two independent variables are correlated, resulting in a highly insignificant estimate for the coefficient in interest in this case as well.

5.3 Government restrictions as an explanation

The main factor affecting travel behavior during this period may instead have been travel restrictions. If the governments in Europe did not issue a travel ban, they still discouraged traveling and unnecessary trips by air, land or sea. Most countries even issued strict lockdowns or stay home orders which meant that people were not allowed to even leave their houses and could only do so to perform necessary tasks like grocery shopping. Naturally, flying outside of the country was extremely difficult if not prohibited during a lockdown. The table below shows the Covid-19 interventions made by some major European countries and the date they were issued. It is very clear that the restrictive measures were issued during the second or third week of March which coincides with the decline of passenger traffic volumes during that same time. Even though there are some differences in how restrictive the measures were and when they were in place, potential passengers perhaps perceived the entirety of continental Europe as a no travel zone. Thus, they were not willing to risk flying without being sure about which country was still open and for how long. Thus, the confusion about which countries are open may have created great uncertainty that discouraged flying even if it was allowed and possible. This may explain why passenger volumes were relatively very low even in countries who chose to remain open and commit only to advising against travelling. For example, Sweden[1].

Table 1: Different restrictive measures employed in some Europe countries during the pandemic

Country	Type of restrictive measurements	Period
Germany	Strict social distancing measures but no travel restrictions	March 22- May/June
Belgium	Nationwide lockdown	March 18 – May/June
Czechia	Lockdown and closed borders	March 12 – May/June
Spain	General confinement orders	March 14 – May/June
France	Strict nationwide lockdown	March 17- May/June
Italy	Nationwide lockdown	March 9 – May/June
Hungary	Lockdown state of emergency	March 11 – May/June
Netherlands	"Intelligent Lockdown" with open airports	March 31 – May/June
Austria	Less strict restrictions with open airports	March 16 – May/June
Poland	Lockdown and closed borders	March 13 – May/June
Portugal	Measurements restricting movement	March 16 – May/June
Sweden	No lockdown but soft restrictions in place	N/A – N/A
United Kingdom	Nationwide lockdown	March 23 – May/June

Note: Table compiling the different restrictive measures employed by some of the European countries in the sample. The sources are government official communication outlets for example website of foreign departments or national news agencies. The period of which during the measures were in place was prolonged several times so we set May/June as an approximate date for when measures were lightened or lifted.

Furthermore, we studied data concerning the general movement of people in Europe provided by Google in its Covid-19 community Mobility Reports (Our world in data, 2020). Metrics on how much time people spent at home, in public spaces or how many people used public transport show the expected results of the stringent measures that sought to decrease people's movement. Basically, most of the European population stayed indoors and avoided enclosed and confined spaces as per their respective government's instructions. In Sweden for example, public transport usage was around 40 percent less than the base line value during the height of the pandemic in the middle of March 2020. Additionally, this "movement" metric was insensitive to the number of Covid-19 cases but more responsive to the government guidelines regarding the use of public transport. This further speaks for the case that the major driver behind the change in volumes of traveling airline passengers was policy and not the spread of the virus.

We further studied statistically how differences in lockdown policies may have affected air travel. This was done by regressing a metric from the google mobility data that measures on a comparable scale how stringent the travel and movement restrictions were in each country. Our results from

[1] See appendix.

these regressions were as expected as we saw a significant negative coefficient indicating a decline of air travel in a country the more restrictive the measures were. These results are displayed as graphs in the appendix.

However, how stringent the governments' measures were still depended on Covid-19 data, as many of these measures were relaxed during the summer when infection figures were much lower. Indeed, several European countries opened, and airports were again relativity busier with more scheduled flights and passengers carried (source). Therefore, it may still be very well that our independent variables had a causal effect on the number of people traveling by air but in an indirect way through government policy which responded to changes in said variables.

6. Conclusion

This paper aimed examine whether the change in the severity of Covid-19 pandemic in European countries has led to a change in the number of passengers carried by airlines across Europe. No plausible effect is found as it seems that air passenger volumes declined in all countries irrespective of the infection rate, the excess mortality rate or the infection rate from the month before. However, the exact mechanism behind this change in behavior among the European populace is not completely certain. Monthly passenger data makes it more difficult to put travel behavior under the lens as the distribution of detected cases across time within each month can vary greatly with random peaks and lows, making the inference that travelers abstained from traveling on airlines due to an increased number of cases highly questionable.

Furthermore, the mechanism behind the decline of air travel would still be ambiguous even if the estimates from our regressions would show the hypothesized and expected results of a negative correlation between the severity of the pandemic and passenger volumes. Although the proposition of travelers glancing Covid-19 metrics to determine their flight destination is not irrational, one should consider several other factors that travelers were likely considering. For example, the fast-paced development of the pandemic, rumors of cancelled flights, the risk of being stranded in a foreign country and the almost daily pandemic related measures issued by the governments of multiple countries. Thus, if "uncertainty" was a quantifiable metric it may have been a better explanatory variable than the severity of the pandemic variables that we used in this paper.

Therefore, we present a more intuitive hypothesis suggesting that passengers were likely not independent agents basing traveling decisions on Covid-19 data. Instead, potential European airline passengers were adhering to directives made by their respective leaders or even more realistically, the practical feasibility of getting on a plane during a global pandemic.

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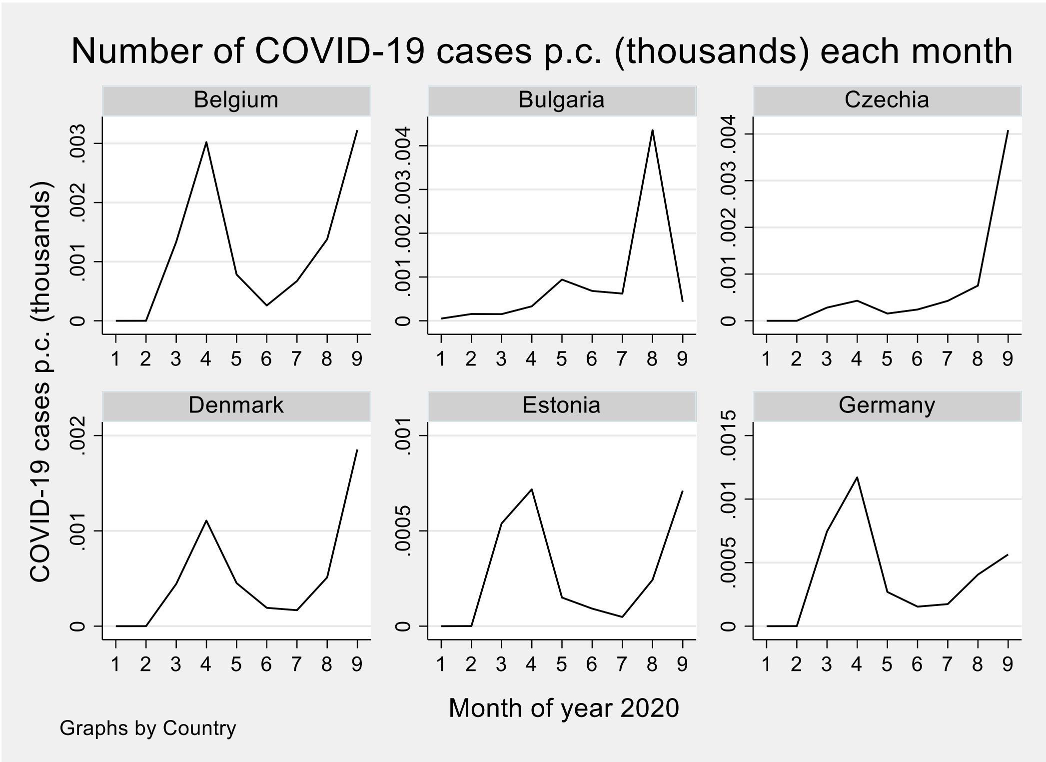
8. Appendix:

Figure 1



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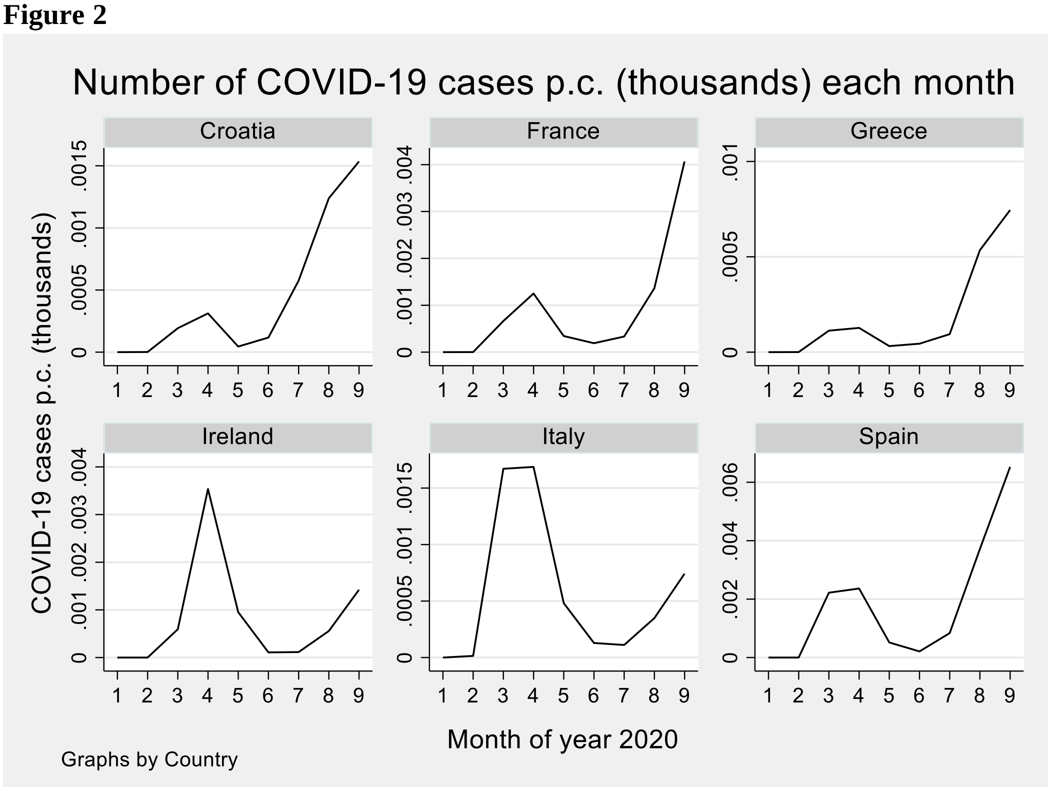

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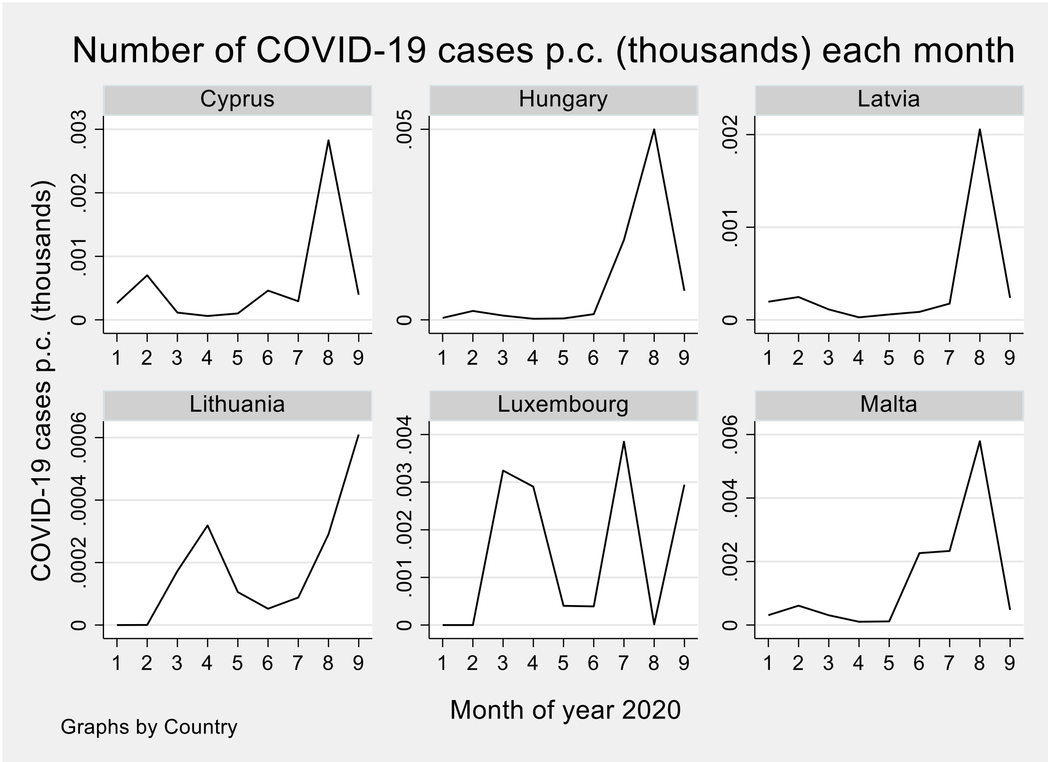

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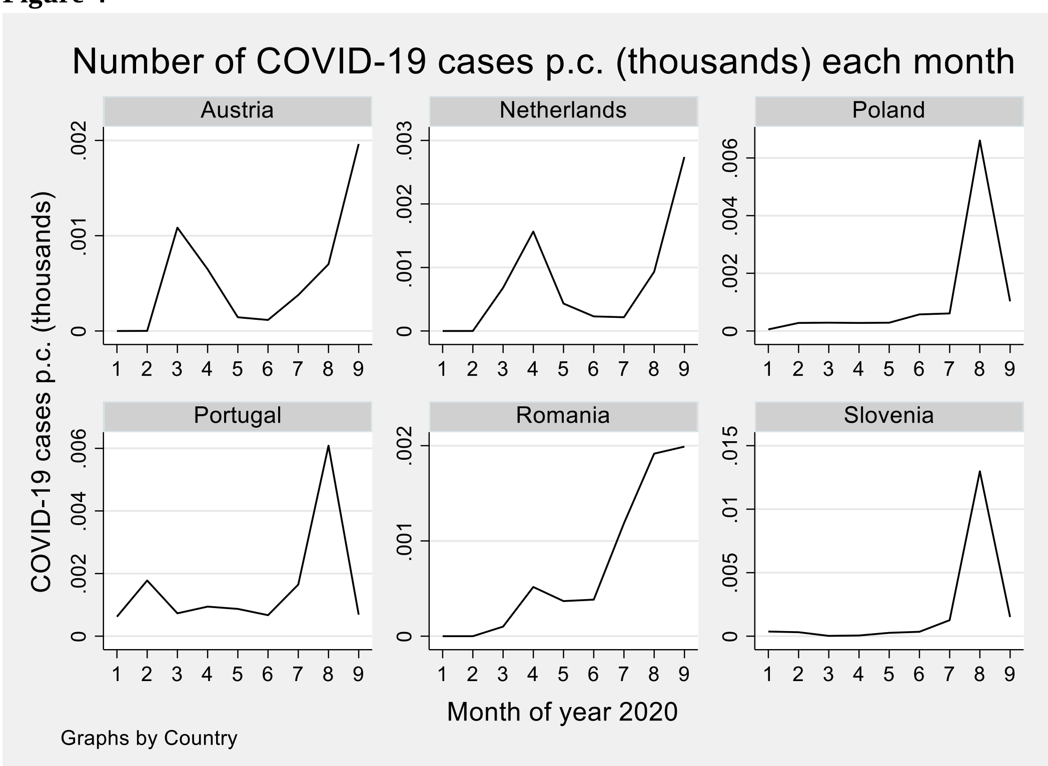

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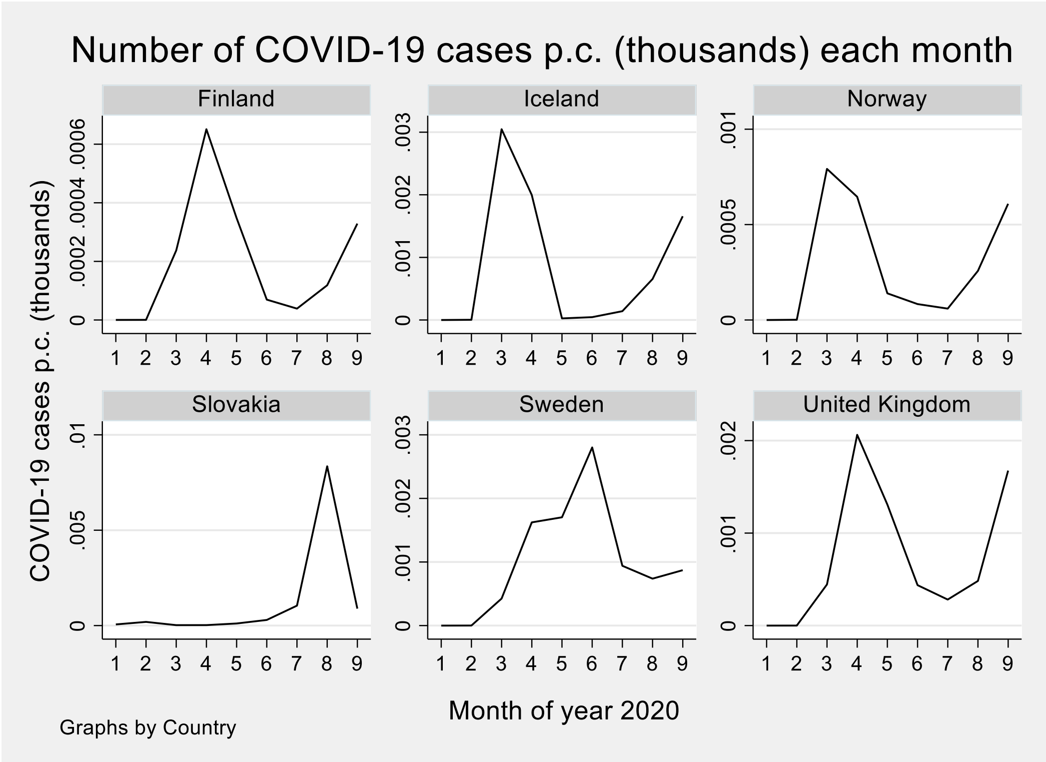

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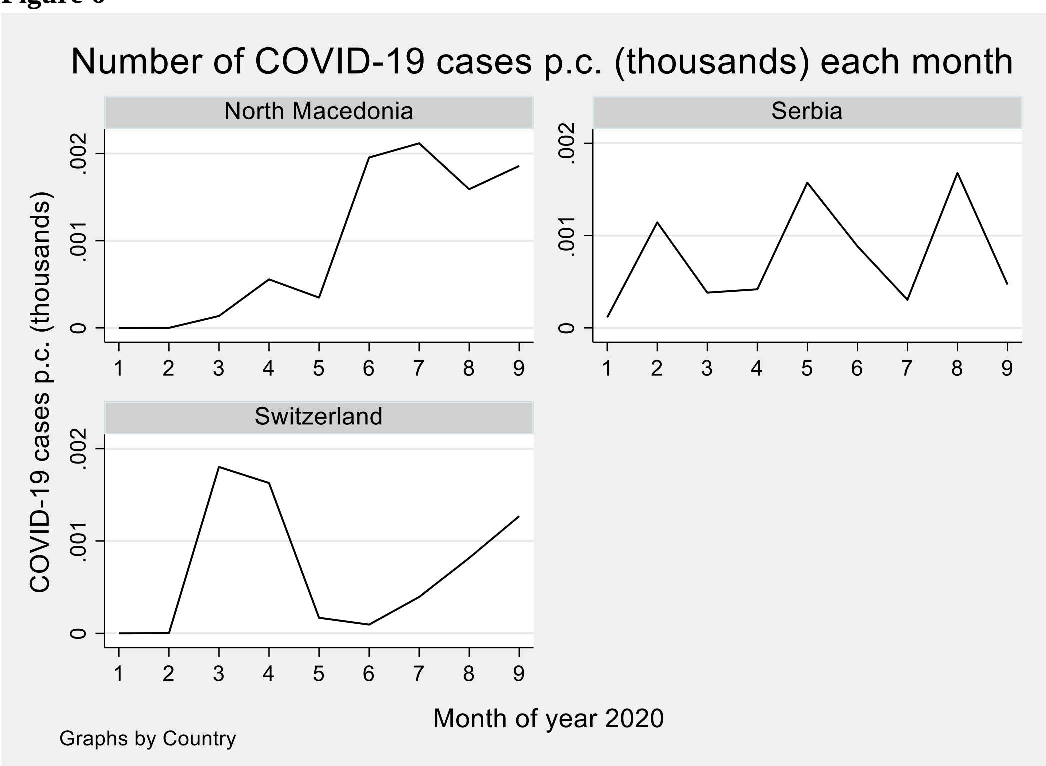


Note: figures 1-6 (previous pages) show graphs representing the number of reported COVID-19 cases per country. The graphs highlight both the hetero- and homogeneity of observed trends with regards to detected cases, where most countries clearly experience a first wave during months 3-4 while and a second wave shortly after midsummer. Other countries however say only one wave after summer in time with other countries experiencing their second wave.

Figure 7

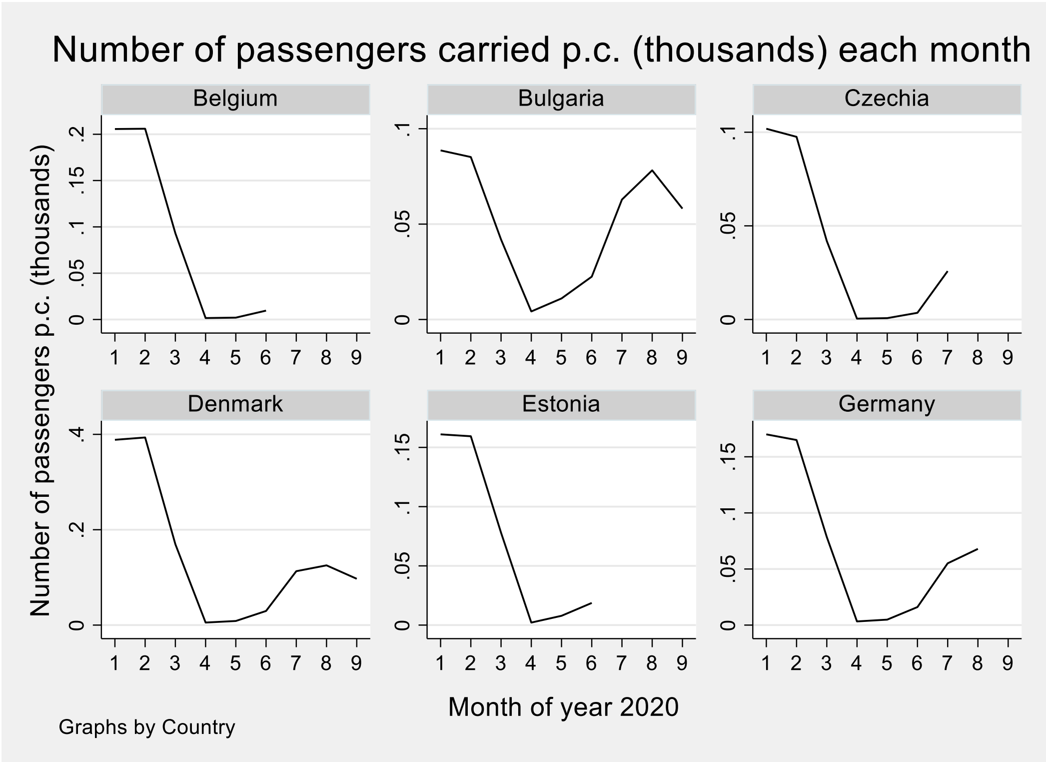
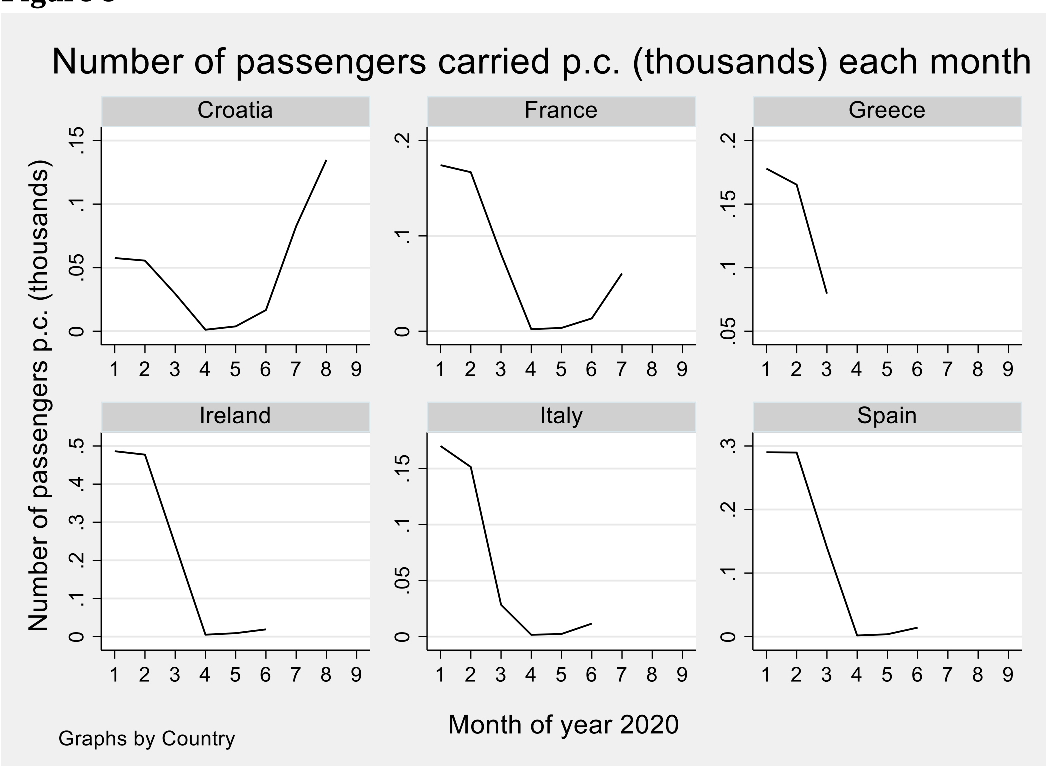


Figure 8



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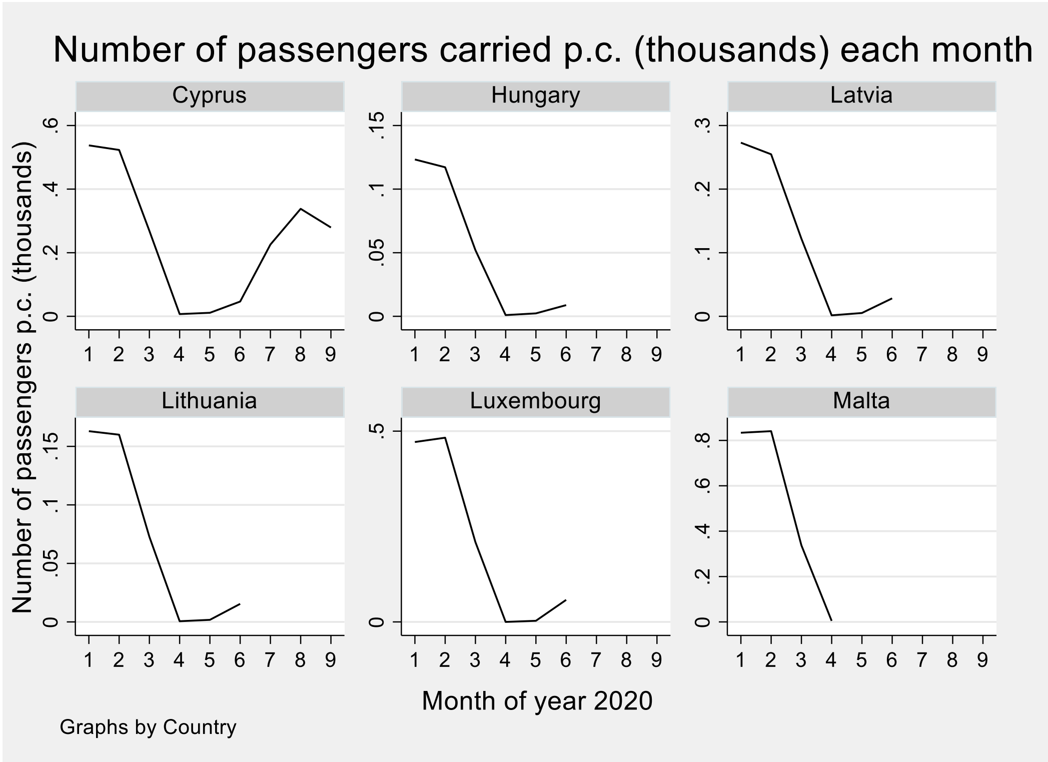

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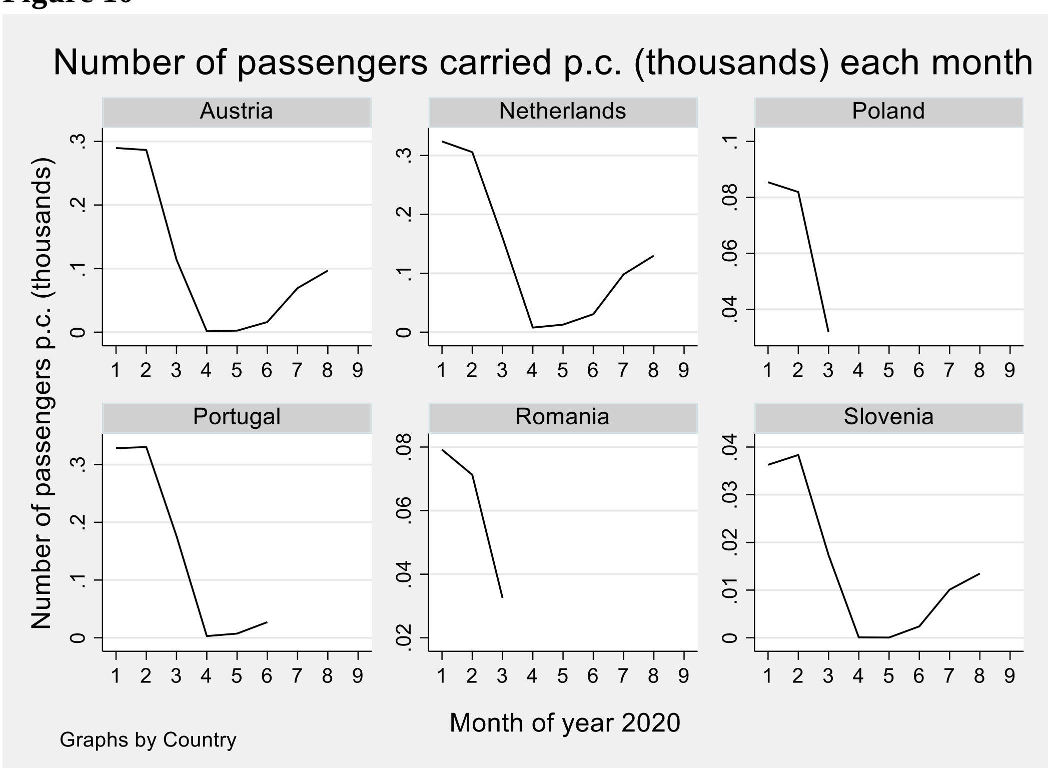

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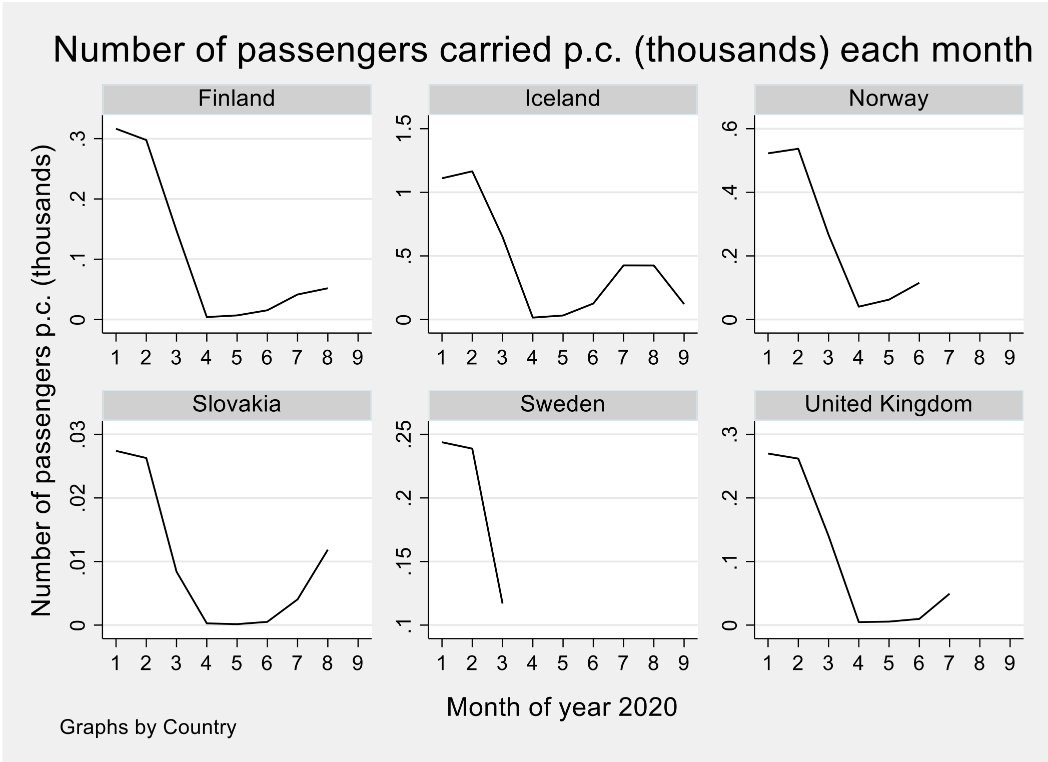

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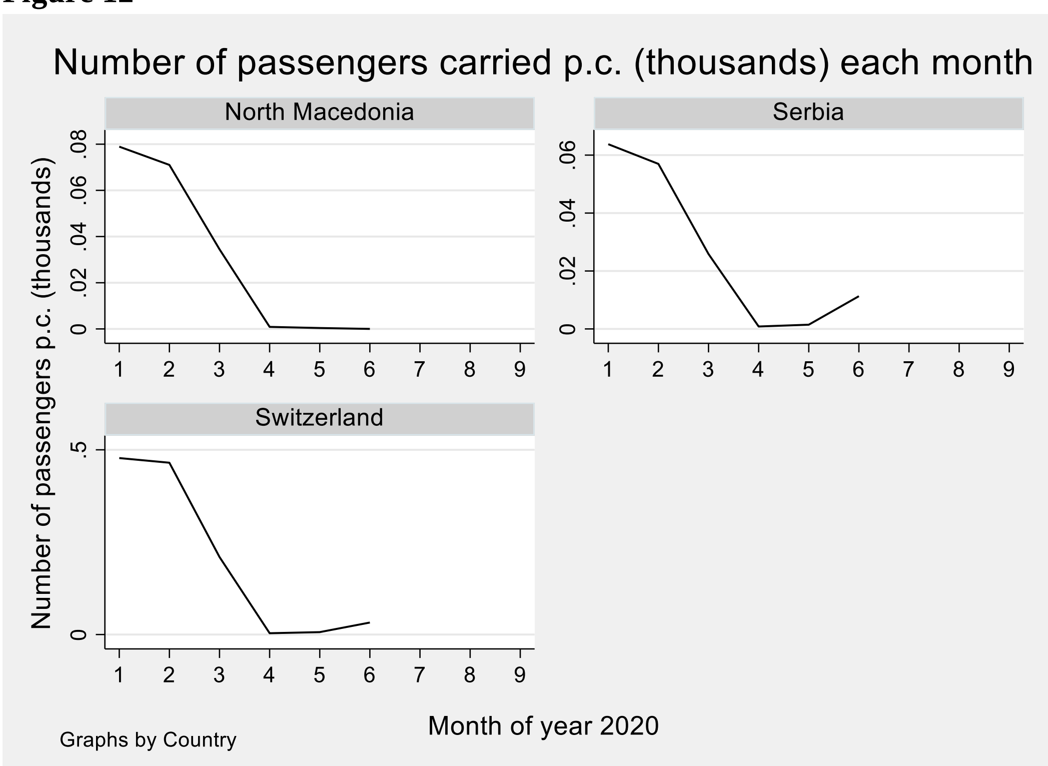
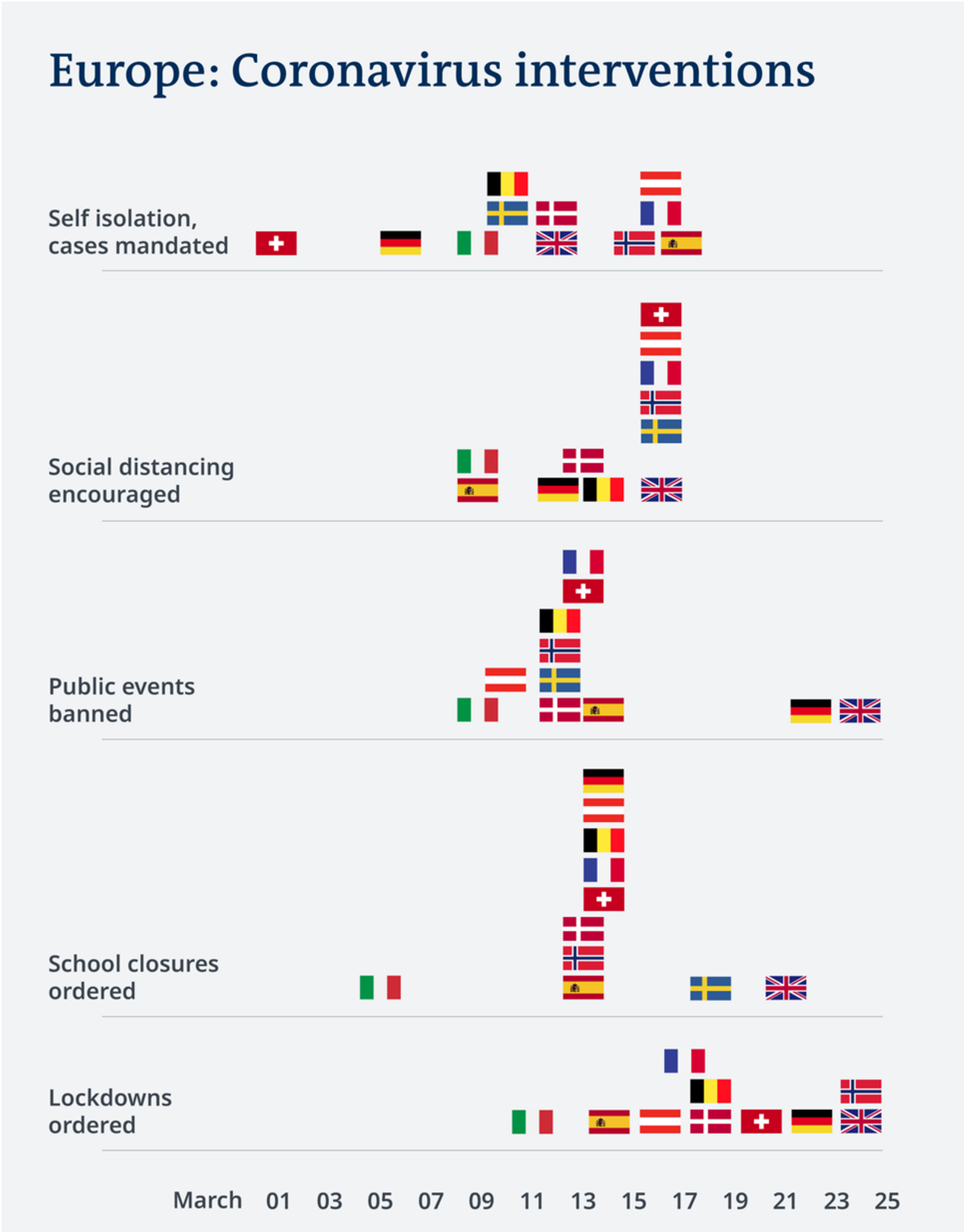


Note: figures 7-12 (previous pages) show graphs representing the number of passengers that were onboard an airplane for each country in thousands. It is observable thar most countries lost 90% of air passenger volumes or more during the first 3-4 months of the year. Some countries experienced a slight rebound while others traffic remained so low that no data was collected during the period.

Figure 13: Different coronavirus interventions in Europe



Note: Compilation made by Deutsche Welle (German news outlet) on the different restrictive measures taken by several European countries during the pandemic.
https://www.dw.com/en/coronavirus-what-are-the-lockdown-measures-across-europe/a-52905137

Figure 14

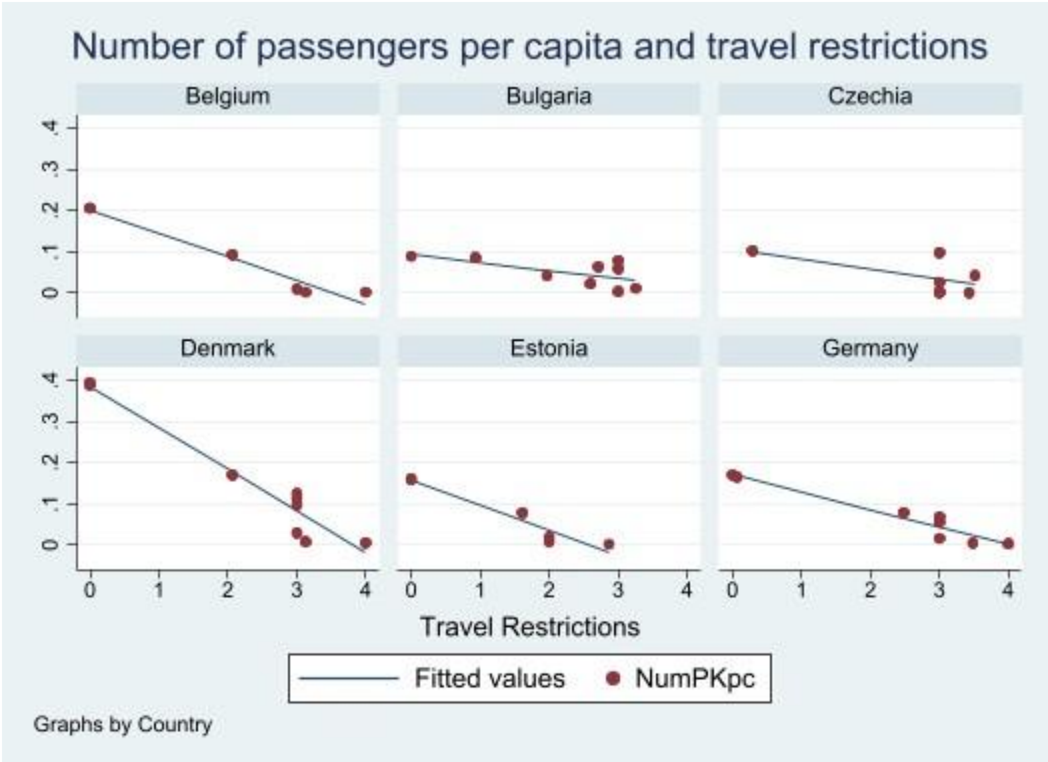


Figure 15

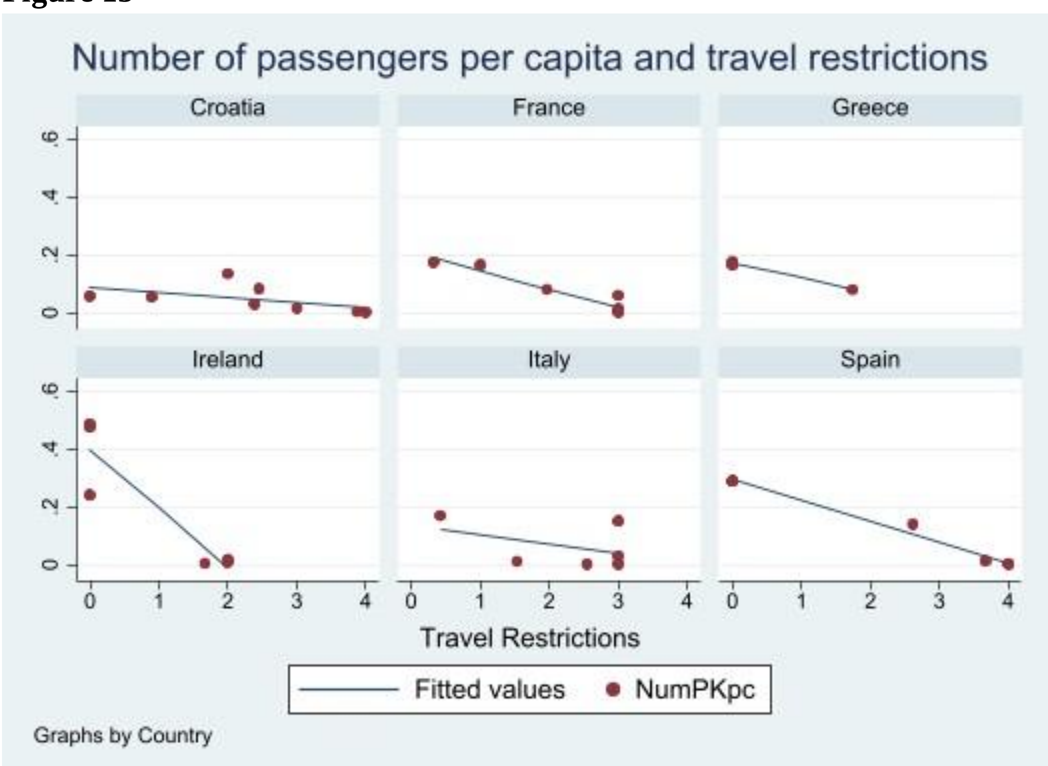
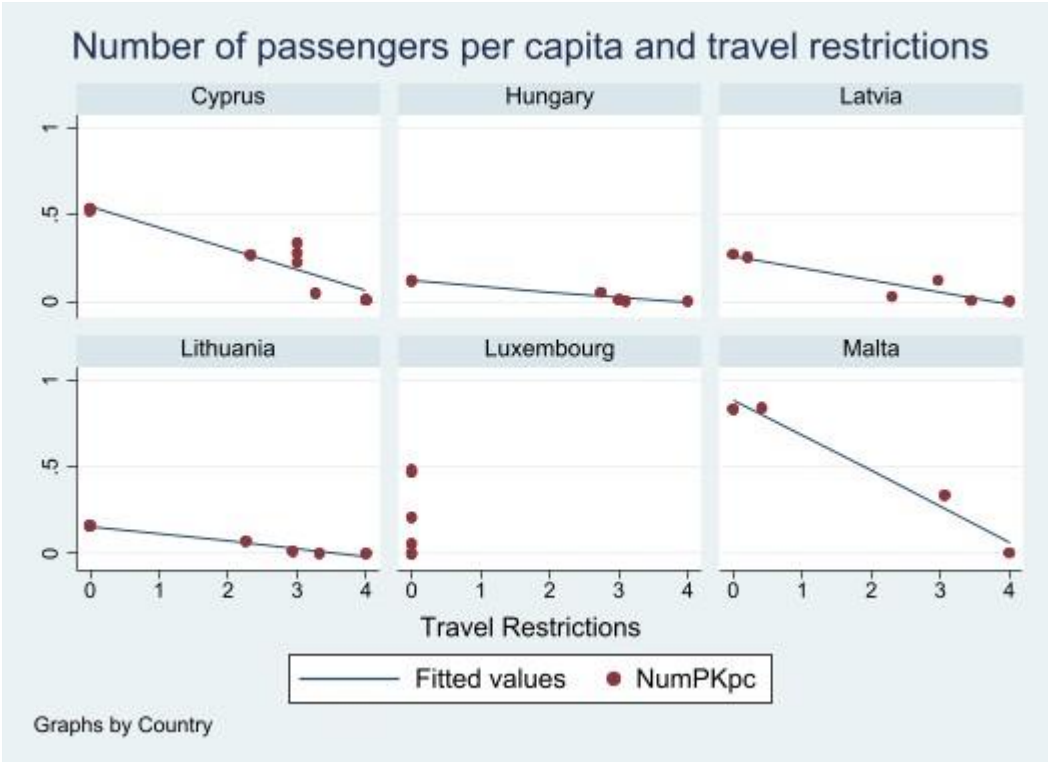


Figure 16



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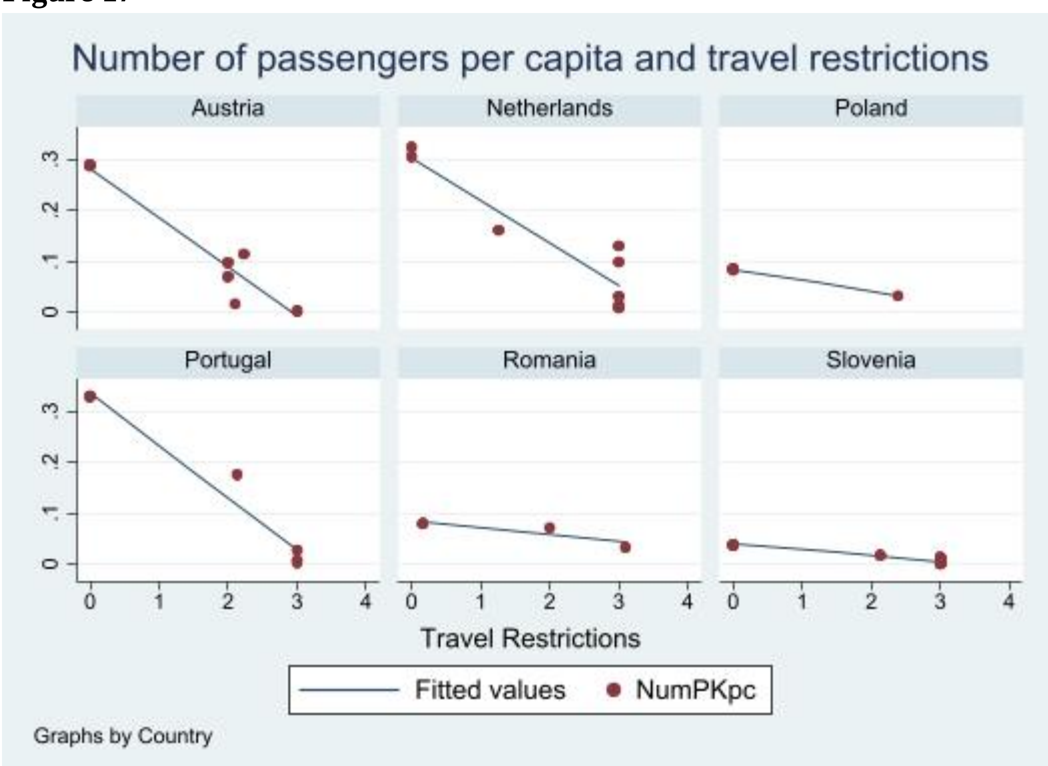

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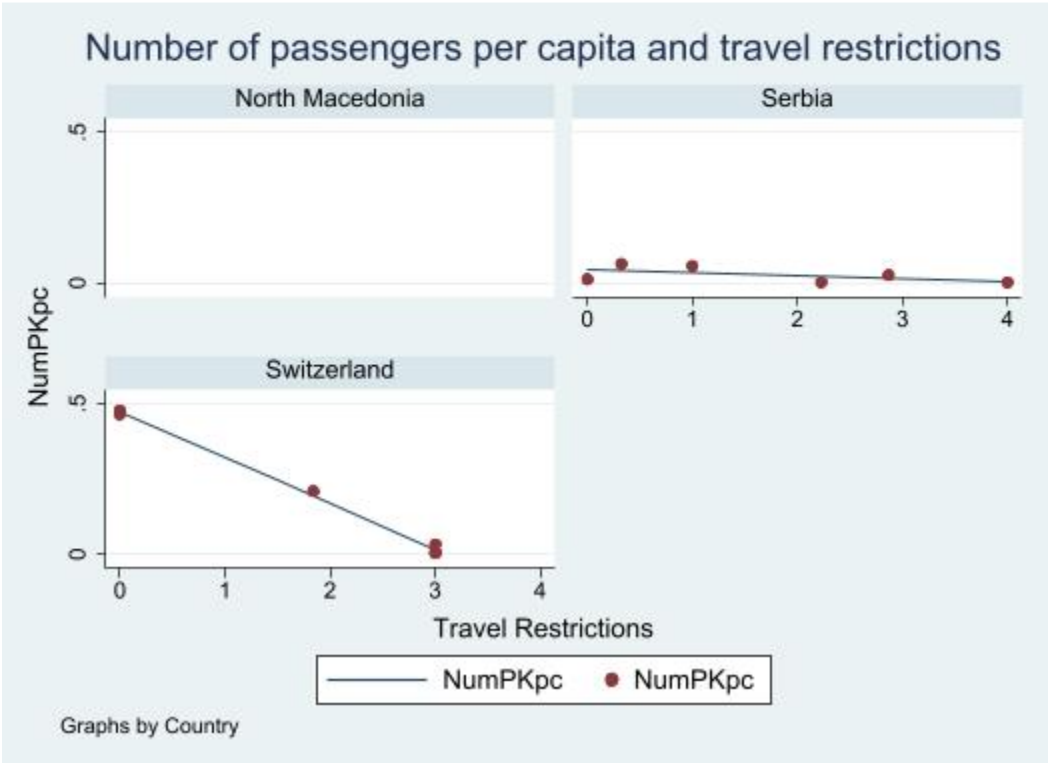
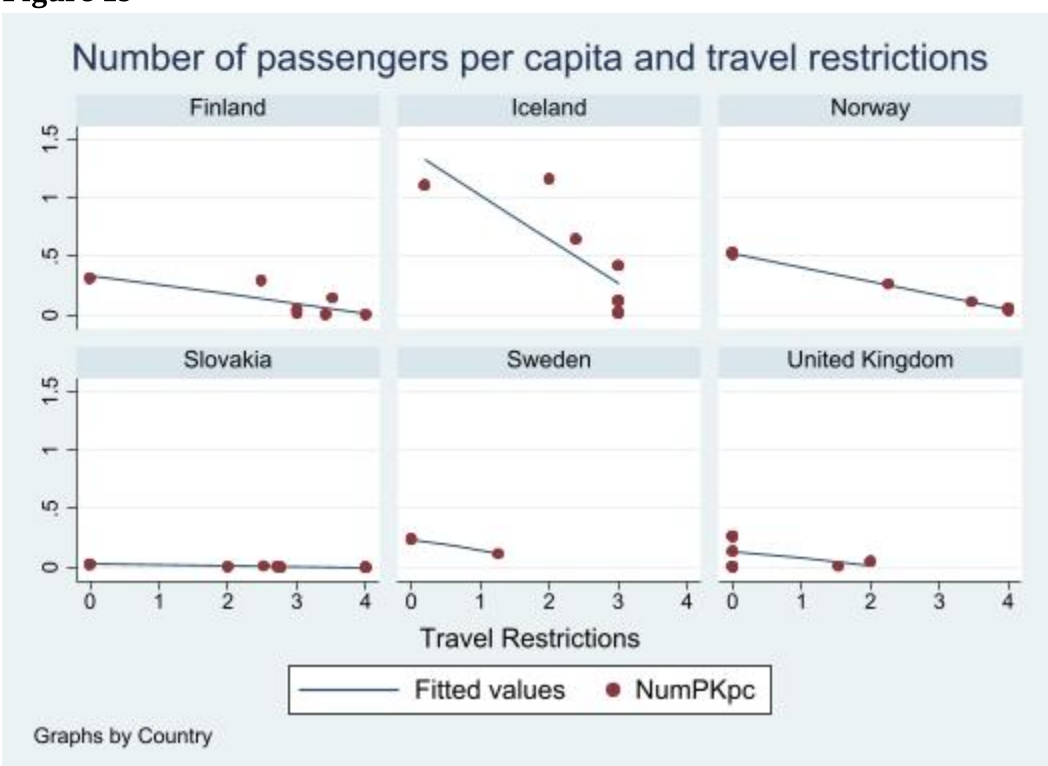


Figure 19



Note: Figures 14-19 are scatterplots depicting the negative relation between the number of passengers per capita and the stringency of travel restrictions introduced in each country (the higher the more restrictive). These graphs were produced from the Google Covid-19 mobility data.