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The Impact of COVID-19 on Air Freight Pricing

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Les membres du jury qui ont évalué ce mémoire ont demandé des corrections mineures.

Résumé

La pandémie de COVID-19 a été l’événement le plus perturbateur à toucher l’industrie de l’aviation depuis ses débuts il y a plus de 100 ans. Des réglementations gouvernementales inédites et des interdictions de voyager ont réduit la capacité de transport aérien de plus de 90 % au plus fort de cette pandémie, menant à une hausse des prix du fret aérien, ces derniers ayant doublé et même triplé dans certains marchés. Dans ce mémoire, je profiterai d’une base de données unique dont l’accès est habituellement restreint, le *Cargo Accounts Settlement System* de l’AITA, pour étudier les facteurs qui ont mené à cette hausse des prix du fret aérien à travers le monde pendant la pandémie de COVID-19. Après une revue détaillée de la littérature portant sur les facteurs qui influent sur le prix du transport de cargaisons, ce mémoire présente une analyse économétrique à partir de données mensuelles recueillies pour la période 2019-2020. Le but est d’évaluer l’influence, sur le prix du transport de cargaisons aériennes, de variables telles que la taille du marché, les changements quant à la capacité, le nombre de cas de COVID-19, la connectivité aérienne et la restriction des déplacements, et cela, pour plusieurs pays et aéroports. Mes résultats montrent que les hausses des prix du fret aérien ont été particulièrement sévères là où la capacité a vu le plus grand déclin, où les cas de COVID-19 étaient particulièrement nombreux, où les restrictions des déplacements étaient strictes et où la connectivité aérienne était déjà forte. La principale recommandation découlant de mes résultats quant aux politiques à adopter est que les gouvernements et les transporteurs aériens travaillent à développer une gestion plus solide de la capacité afin de rendre l’industrie du fret aérien plus résiliente aux chocs s’apparentant à ceux ressentis pendant la pandémie.

Mots-clés : prix du fret aérien, pandémie COVID-19, industrie de l'aviation, compagnies aériennes, gestion de la capacité.

Abstract

The COVID-19 pandemic is the largest disruptor to hit the aviation industry since its beginnings over 100 years ago. Novel government regulations and travel restrictions reduced capacity by over 90% at the peak of the pandemic, causing air freight prices to more than double and even triple in some markets. In this thesis, I take advantage of a unique and difficult to access database – IATA's Cargo Accounts Settlement System – to study the drivers of air freight price hikes across the globe during the COVID-19 pandemic. Following a detailed literature review of the factors that impact cargo pricing, I perform an econometric analysis on a panel of monthly data that I have collected for the period 2019-2020 to evaluate the influence of market size, capacity changes, prevalence of COVID-19, air connectivity and travel restrictions on air cargo pricing movements across countries and airports. My results show that air cargo price hikes were particularly severe in locations with a larger drop in flight capacity, a higher COVID-19 prevalence, higher travel restrictions and a higher air connectivity. The main policy recommendation of my findings is that governments and air freighters need to develop a stronger capacity management if they want to make the air freight industry more resilient to future shocks of pandemic proportions.

Keywords: air freight yield, COVID-19 pandemic, aviation industry, freight pricing, airlines, capacity management

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List of Abbreviations

ATAG: Air Transport Action Group

ACI: Air Connectivity Index

CASS: Cargo Accounts Settlement System

COVID-19: Novel Coronavirus 2019

CTK: Capacity Tonne-Kilometers

EU: European Union

FTK: Freight Tonne Kilometers

IATA: International Air Transport Association

ICAO: International Civil Aviation Association

JIT: Just in Time

OxCGRT: Oxford COVID-19 Government Response Tracker

PPE: Protective Personal Equipment

WHO: World Health Organization

YOY: Year Over Year

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1. Introduction

1.1. Problem Identification

The COVID-19 coronavirus pandemic introduced novel changes to several facets of the world's social and economic life. Due to the fear of the virus spreading further, governments worldwide implemented restrictive policies that were unprecedented, limiting people's movement to contain the spread of the coronavirus. This impacted a multitude of modes of transport including air, road, and water transportation. In the months following the outbreak, the air industry has proven to be the worst impacted of all modes of transport (Abu-Rayash & Dincer, 2020).

In May 2020, 100% of all air travel destinations had put some form of travel restrictions in place, and 85% of them had completely or partially closed their borders. These global movement and travel restrictions resulted in more people staying home than ever before and put the aviation industry in a critical situation. Airlines are predicted to have lost up to 84 billion USD in net profits in 2020 (ICAO, 2020). This greatly exceeded the impact of all previous disruptive events including the 9/11 attacks on New York City, the Severe Acute Respiratory Syndrome (SARS) in Asia in 2003 and the 2008 economic crisis (Goetz & Graham, 2004). At the peak of the SARS epidemic in Asia, Asian airlines saw their monthly revenue decrease by 35% compared to their pre-SARS crisis numbers. This was the worst disease outbreak in the history of aviation until the coronavirus pandemic. Previous sanitary crises were short and had a V-shaped recovery, meaning quick and sharp, but the coronavirus pandemic is unlikely to have such a recovery scenario(IATA, 2020b).

Previous crises had short-term effects on the demand for air travel, which are showcased in fig1.in the form of small dips that recover quickly (ICAO, 2020).

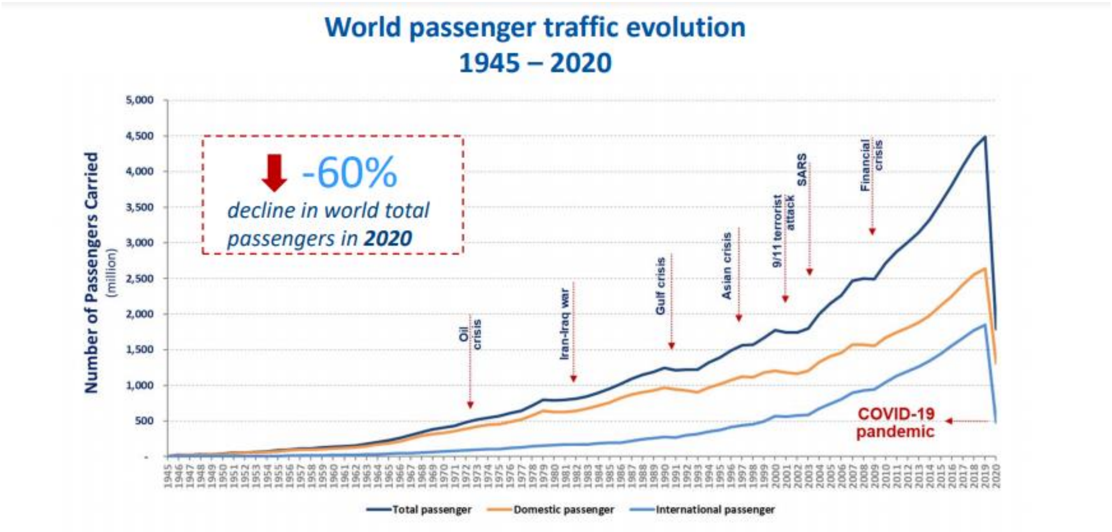


Fig. 1. World passenger traffic evolution 1945-2020

Source: (ICAO, 2020)

The impact on aviation was not limited to passenger travel, the restrictions and border closures resulted in a sharp decrease in available capacity for air freight in 2020. The severity of the decline did not match that of passenger travel, but nonetheless, at its peak, the year-over-year capacity reduction exceeded 30%.

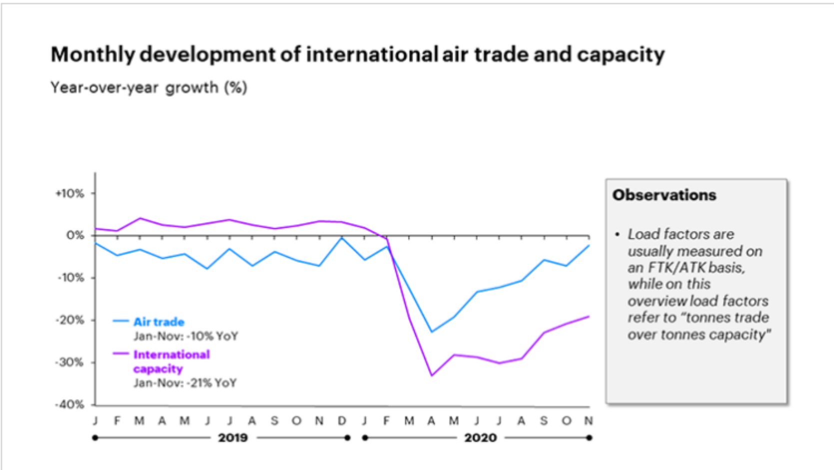


Fig. 2. Monthly change of air trade and capacity

Source: (STAT TIMES, 2021)

This unprecedented decrease in available air freight capacity and volume transported was accompanied by a historical increase in prices. As shown in fig.3, at the height of the pandemic, the yield per kg for air freight increased by more than 250%.

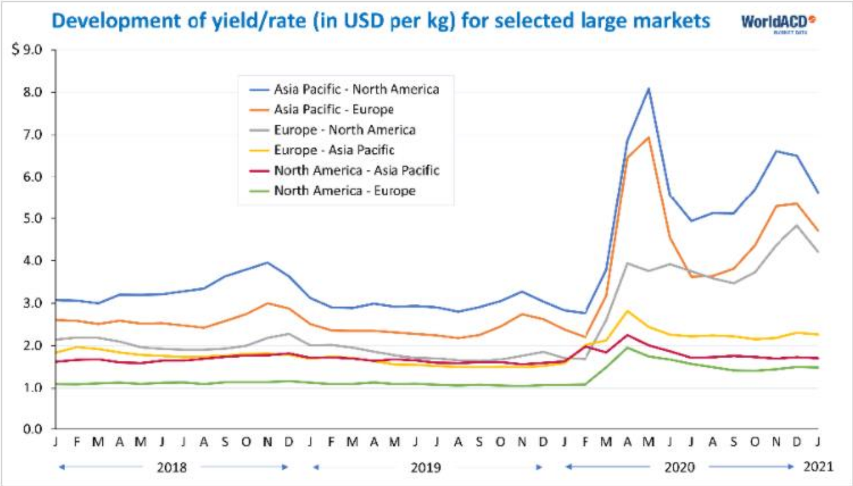


Fig. 3. *Change in air freight yield*

Source: (STAT TIMES, 2021)

COVID-19 was first detected in Wuhan City, Hubei Province in China in December 2019 and was initially diagnosed as a pneumonia of unknown etiology. Later, the virus was named SARS-COV-2 due to the similarities it shared with the previous SARS virus. The disease is known as Coronavirus disease or COVID-19(Lu et al., 2020). The virus initially spread only in China from its centre in Wuhan, which went into a strict lockdown during the first few months of 2020. By February 11th, the WHO reported that the virus had spread to over 28 countries. On March 11th, the virus was declared by the WHO to be a global pandemic (Lai et al., 2020). As of March 2021, the virus has infected over 127 million individuals in 192 countries and territories and caused over 2.7 million deaths (John Hopkins, 2021).

Like the spread of the virus, the impact on air traffic was also initially limited to China. This took the form of cancellations of domestic and international flights in Macao, Taiwan, Hong Kong, and Mainland China, as seen in fig.4. (ICAO, 2020).

Fig. 4. *Domestic and international flight cancellations in China.*

Source: *(ICAO, 2020)*

As the months progressed and the virus started spreading to other countries, the impact on global air traffic became noticeable across all continents (ICAO, 2020).

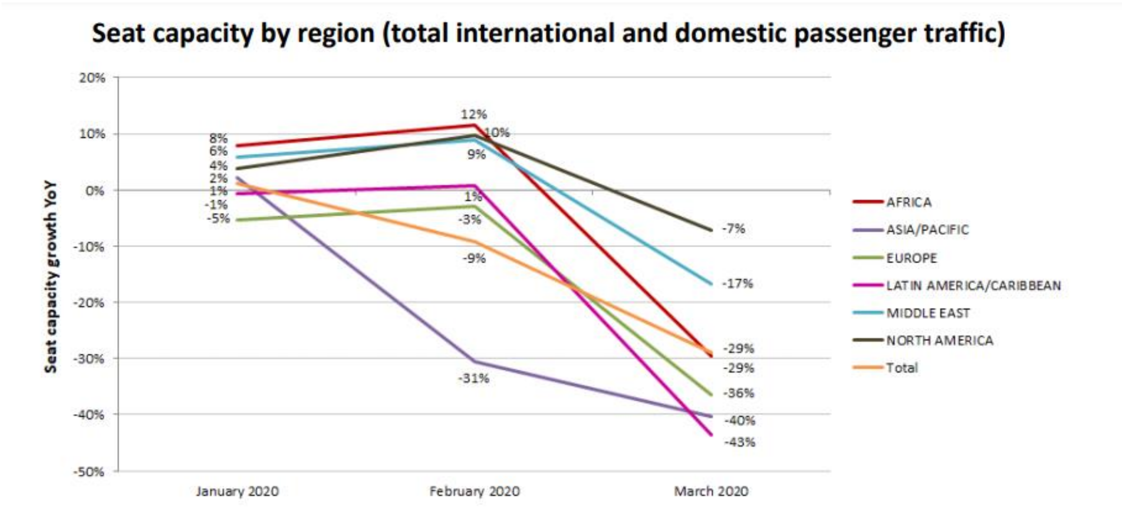


Fig. 5. *Change in seat capacity per region after the pandemic.*

Source: *(ICAO, 2020)*

This drastic impact on the aviation industry did not go unnoticed as it is closely correlated with global economic growth and is considered one of the important sectors that contribute to it. The Air Transport Action Group (ATAG) estimated that 65.5 million jobs around the world are tied to the aviation industry (ATAG, 2020).

World air cargo traffic grew by an average of 4.3% between 2011 and 2019 (Boeing, 2020). The value of the air freight transported is estimated at over 6 trillion USD worth of goods annually. Despite handling under 1% of the world freight by volume, it represents over 35% of the value of the global trade (IATA, 2016). This industry report attributes the popularity of air freight to its ability to handle various shipment sizes. Air freight is also ideal for time-sensitive shipments like perishables and pharmaceuticals, and above all, it is one of the most secure modes of delivery, especially for high-value commodities. Air transport, both passenger and cargo, has become a significant economic indicator and a trade stimulator. Air connectivity, an indicator defined as the level of concentration of the network and the ability of passengers to move within it with a minimal amount of connections and at the lowest cost (ICAO, 2013b), became a key indicator for economic growth. An increase of one percent in the Air Connectivity Index translated into an increase of 6.3% in total exports and imports (Arvis & Shepherd, 2016).

1.2. Research Question

Since the start of the pandemic, several papers and dissertations were written about the impact of COVID-19 on the aviation industry from the point of view of passenger traffic (Suau-Sanchez et al., 2020), airport business (Serrano & Kazda, 2020) and (Forsyth et al., 2020), market value of airlines (Maneenop & Kotcharin, 2020) and environmental impact (Ming et al., 2020)and (Dutheil et al., 2020). However, to the best of my knowledge, very little research has been done on the impact on air cargo prices.

The question we will try to answer in this paper is: *How did the COVID-19 pandemic affect air freight pricing? And what are the main drivers behind the changes in pricing?* As it will be discussed in the literature review, several factors could impact the pricing and that includes the changes in capacity, air connectivity and government policies (in this case the governmental travel restrictions following the change in the number of COVID-19 cases).

1.3. Structure of the Thesis

Chapter two of the thesis will cover the literature review and what has been previously written about air freight and possible factors that impact it. This starts with an overview of the history of air freight, how freight shipping works and the main players in the industry. This is followed by an analysis of the factors that could impact the air freight and the demand for it. We then focus on air connectivity, its purposes and the different measurement methods used to quantify it. And finally, we introduce previous research that was written about capacity changes and its impact on freight yield.

Chapter three gives a contextual description of the COVID-19 pandemic including governments' responses to the outbreak with a focus on travel restrictions. We then investigate the impact of these restrictions on air connectivity and capacity changes including examples of airlines reaction plans to these new changes in regulations.

Chapter four introduces the main variable we will be analyzing in this thesis which is the air freight yield. We then introduce our regression model and its various dependent variables.

Chapter five presents a descriptive analysis of every variable and its data set. To identify possible patterns and trends, it then introduces the results of the regression analysis and its findings.

Chapter six includes the overall conclusion of the thesis and explores possible limitations to this research and possible future research that can fill these gaps and limitations.

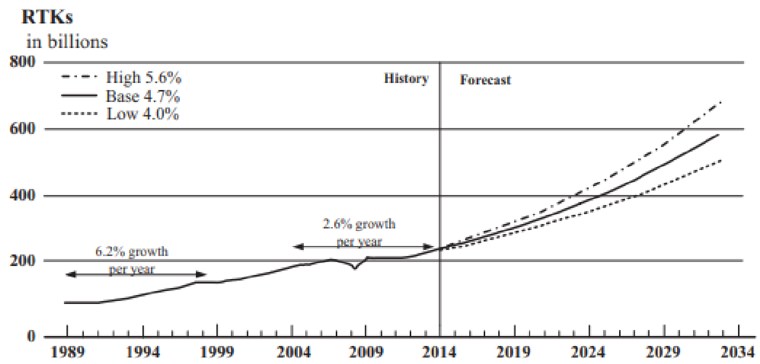
2. Literature Review

2.1. Air Freight History and Background

The origin of international air freight dates back to the late 1920s when airmail and diplomatic consignments were transported by European airlines between Europe and other nations overseas. Since then, air freight has connected the world's major trading routes and become one of the main shipping modes, transporting over 35% of the world's traded goods by value (IATA, 2021). This share of trade has been increasing steadily for the past 50 years (Hummels, 2007).

Air transport, including both passenger and freight, is considered as key contributor to the development of downstream sectors according to the OECD. It enables several economic activities through the trade in goods and also services, and through the transportation of people (OECD, 2020). Air freight is especially popular for high value to weight merchandises and for perishable commodities, including electronics, high-end fashion items, temperature-sensitive pharmaceuticals, etc. (Budd & Ison, 2017).

Air freight represents an important part of the global transportation system due to the continuous increase in global trade and the increasing demand for faster shipping. This is especially true in the case of Just in Time (JIT) strategies and the continuous efforts of companies to keep inventory levels low through frequent replenishment (Wen et al., 2020). As shown in fig.6, this growth led air cargo volumes to double in volume every 10 years since 1970, representing a 50% faster growth compared to passenger transport (Feng, 2015). Prior to 2020, industry forecasts predicted that the air cargo market would continue to grow by 4.7% each year and triple in revenue by 2033 (Boeing, 2015).

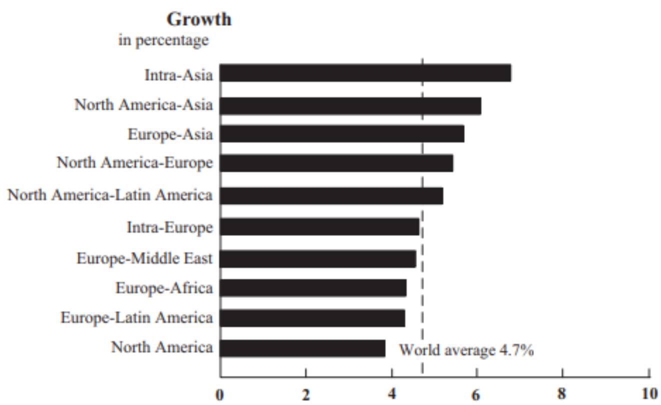


Growth of world air cargo.

Fig. 6. *Growth of world air cargo*

Source: (Feng, 2015)

This continuous growth is mainly attributed to the expansion in the Asian market that has transformed into the largest manufacturing hub in the world. Fig. 7 below clearly shows how the freight growth between Asian countries, as well as between Asia and other continents, continues to outperform the global industry (Feng, 2015).



Asian cargo markets continue to lead industry growth.

Fig. 7. *Asian cargo markets continue to lead industry growth*

Source: *(Feng, 2015)*

Air cargo moves shipments from origin (shipper) to destination (consignee) by air. As Fig.8 shows, many other actors may also be involved in the process. The shipment can be handled through a freight forwarder who organizes the shipments on behalf of the shippers, a road transport provider, and an airline. The other option is to go through an integrator (like FedEx for example) who owns and handles the freight to complete the value chain. In the case of the non-integrator supply chain, the shipper who needs to send a commodity contacts a freight forwarder who acts as a middleman between the shipper and the airline. Freight forwarders negotiate preferential pricing with the airlines by booking large volumes ahead of time. Road transporters cover the portion of the shipping between and after air travel and this can be either managed by the airline itself, the freight forwarder or a third party. The airlines or carriers provide the freight forwarder with various services, including booking, pickup, packaging, sorting, loading, cargo tracking, etc. (Feng, 2015).

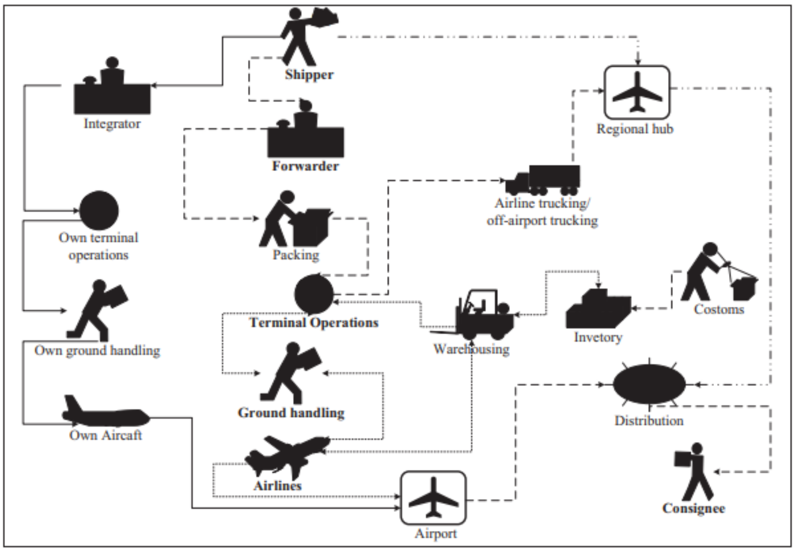


Fig. 8. *A landscape of air cargo operations*

Source: (Feng, 2015)

Pricing varies depending on the types of services provided by the carrier. Extra services are billed as surcharges on top of the basic weight charges per kg. Pricing varies based on the service priority and cargo type such as dangerous goods, live animals, pharmaceuticals, etc. The weight charges per kg are applied to the actual weight or volume weight, whichever is higher (Nobert & Roy, 1998).

The airline issues a shipping document known as an air waybill that includes all the information about the shipment including its dimensions, weight, value, unit count, type of commodity and corresponding charges. This document is used for cargo verification along the shipping process, customs clearance, and payment through CASS (Cargo Accounts Settlement system) or directly between the parties involved. The airline also takes care of scheduling the shipments, forecasting demand, verifying the packages for customs, etc. Whereas the freight forwarder arranges the documents for this, books road transport and acts on behalf of the shipper to guarantee the shipments make it to their destinations. Airports can be involved in warehousing, verifying dangerous goods regulations and security clearance. A detailed overview of the activities of each entity along the air shipping chain is listed below (Feng, 2015).

Activity/operation of key players in air cargo service.

Player	Activity/operation	
Shipper	– Make booking – Negotiate best rates – Select priority – Preparation of documents-customs, insurance	– Track shipments – Accept billings and make payments – Place claims and repair changes
Forwarder	– Make booking – Negotiate best rates – Select priority – Preparation of documents-customs, insurance – Track shipments – Accept billings and make payments – Place claims and repair changes	– Booking acceptance – Bid for space-allotments – Distribution – Warehousing – Invoice shipper – Interact with multi-modal carriers – Massaging and transaction ability – Consolidation of shipments
Airline	– Schedule cargo flight – Plan cargo routs – Initialize and open flights for booking – Negotiate rates – Publish prices/rates – Provide distribution channels – Forecast cargo capacity – Segment and forecast cargo demand – Plan for no-show, cancellations and overbook – Set-up bid prices – Accept/reject shipments orders – Maximize revenue – Improve load factors – Track shipments – Accept bids from customers – Allocate cargo space-allotments – Resource management of terminal staff – Accept shipments tendered – Dangerous goods control – Package validation	– Shipment prioritization – Shipment re-accommodation – Plan loading of cargo-build, containerize, etc. – Unload cargo – Load balancing – Warehousing – Obtain/send flight manifest – ULD management-track, inventory, repairs, etc. – Service reliability – Track and re-route refusals – Offer production services-express, next day – Track shipments, containers – Invoicing/ billing – Prorating – Interline billing – Revenue accounting – Sales accounting – Claims management – Receive/send updates on arrival – Receive/send updates on delivery – Massage interactions
Airports	– Warehousing-storage – Customs – Security clearance – Dangerous goods control	– Package validation – Notify captain – Facilitate smooth cargo operations
Consignee	– Track shipments – Accept billings and make payments	– Place claims and repair charges

Table 1. Activity/operations of key players in the air cargo service

Source: (Feng, 2015)

2.2. Structure of the Air Cargo Industry

Air cargo transport is done by two types of airlines: integrated express carriers and passenger and cargo combination airlines. Integrated airlines run freighter-only fleets and sell most of their capacity to freight forwarders, although they sometimes also sell excess capacity to shippers. Integrators include carriers such as FedEx, UPS, DHL, and TNT. Passenger and cargo carriers are called combination airlines and they carry freight, express packages and mail in the belly of a passenger aircraft or in a dedicated freight aircraft (Feng, 2015). Integrators have control over all the steps and assets from shipper to consignee, including physical assets such as trucks and aircraft.

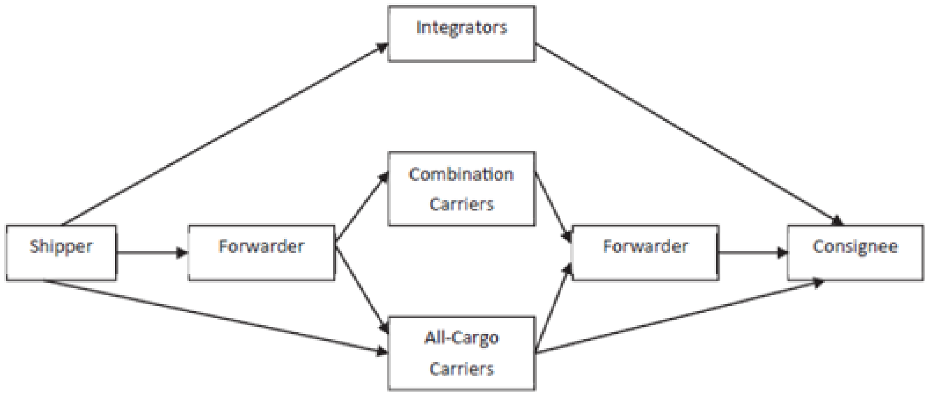


Fig. 9. *Air cargo delivery business model*

Source: (Kupfer et al., 2017)

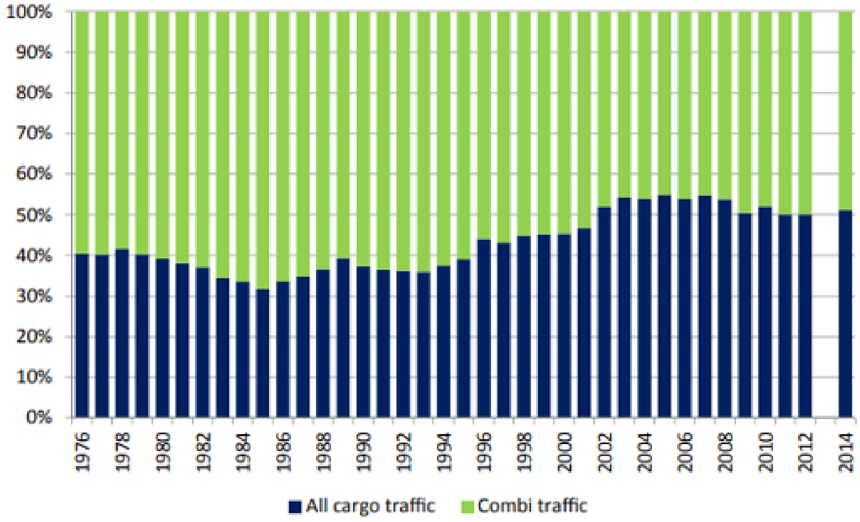
Integrators, such as FedEx and UPS, remain in the top 3 cargo carriers by scheduled FTK according to Table 2 (Air Cargo News, 2020).

Rank	+/-	Airline	2019	Y-o-Y %	2018	Y-o-Y %
1	0	Federal Express	17,503	0.0	17,499	3.8
2	+1	Qatar Airways	13,024	2.6	12,695	15.4
3	+1	United Parcel Service	12,842	3.1	12,459	4.3
4	-1	Emirates	12,052	-5.2	12,713	0.0
5	0	Cathay Pacific Airways	10,930	-3.1	11,284	5.2
6	0	Korean Air	7,412	-5.5	7,839	-2.2
7	0	Lufthansa (1)	7,226	-2.3	7,394	1.0
8	0	Cargolux	7,180	-1.9	7,322	0.1
9	+3	Turkish Airlines (1)	7,029	19.3	5,890	24.6
10	0	China Southern Airlines	6,825	3.5	6,597	6.9

Table 2. Top 10 air cargo carriers by scheduled FTK, 2019

Source: (Air Cargo News, 2020)

Air cargo freight can be divided into two categories: all-cargo traffic which is flown in freighter airplanes and combi traffic which is flown in combi or passenger airlines. Freighters are used in markets where passenger demand is low and cargo demand is high or when cargo dimensions or its hazardous nature prevents it from being loaded into passenger planes. The graph in Fig.10 below shows that, despite the increase of the share of all cargo traffic up to 2008, it has since decreased to about 50% (Kupfer et al., 2017)



Evolution of the share of all-cargo and combi traffic (in FTKs), 1976–2014.

Fig. 10. *Evolution of the share of all cargo and combi traffic in FTKs, 1976–2014*

Source: (Kupfer et al., 2017)

This changed after the 2008 economic recession, mainly due to the volatility in oil prices, political instability and the introduction of new environmental targets that eroded the profit margins of the traditional air freight market. Since 2008, over 850 freighters have been withdrawn from service, with 500 being scrapped and 350 placed in storage (Budd & Ison, 2017)

The popularity of combi traffic is mainly due to the additional belly freight capacity that the growing fleet of wide-bodied passenger airplanes offers. This provided excess capacity that could be sold at a marginal cost since most of the operating costs of combi flights can be recouped through passenger revenue. This allowed belly freight, in certain conditions, to be sold at a lower rate than freighters, while still generating over

30% more profit. In addition, high load factors of around 80% are driving more airlines to shift away from dedicated freighters with their lower average load factor of around 46% (Budd & Ison, 2017).

While the overall global trend shows a shift away from freighters, there are however historical variations in the use of passenger flights belly vs. freighters for capacity as well as differences per region as some continue to increase their freight fleet. The Asia to North America trade lane holds one of the highest rates of freighter use, representing 62% of the total volume. This number goes down to 48% between Asia-Pacific and Europe and 35% between Europe and North America (STAT TIMES, 2020a).

Emerging economies represent an exception to the global shift towards belly freight. Middle Eastern airlines such as Turkish, Etihad, Emirates and Qatar airways are increasing their freighter fleet. Airbus predicts that these markets will account for most of the 800 new freighters forecasted to be ordered over the next 20 years (Airbus, 2015).

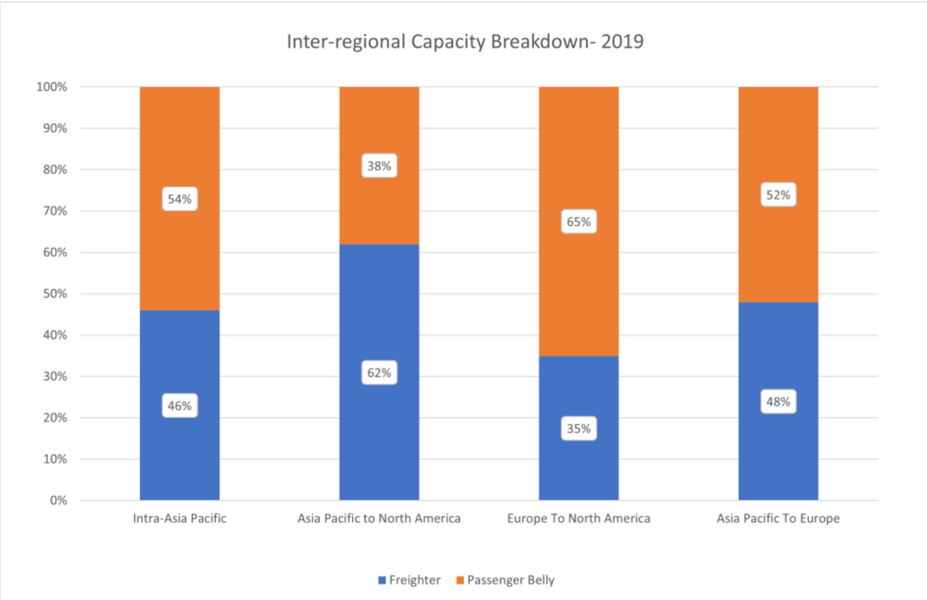


Fig. 11. *Freighter and belly capacity breakdown by region for 2019*

Source: *Seabury data through Stat Times* (STAT TIMES, 2020a)

The regional breakdown between freighter and passenger belly capacity deviates from the average global 50%. This ratio is lower between Europe and North America at 35% freighter vs. 65% passenger belly, and it is highest between Asia-Pacific and North America at 62% freighter to 38% passenger belly.

2.3. Air Freight Pricing and Demand Elasticity

Airfreight has always been an indicator of the world trade and of the state of the economy. The events of September 11, 2001 and the economic crisis of 2008 both caused a decrease in both air freight and world trade (ICAO, 2013a).

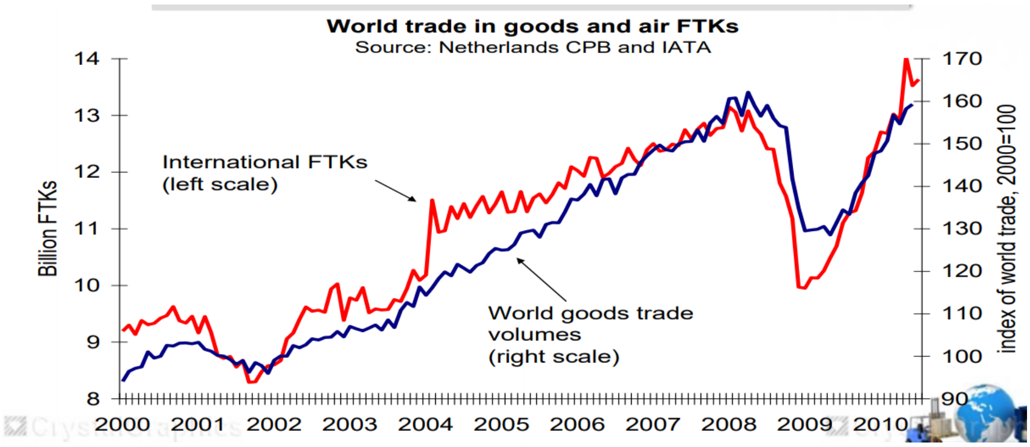


Fig. 12. *World trade in goods and air FTKs*

Source: (ICAO, 2013a)

Air cargo and trade growth are closely correlated. When plotted on one graph, as shown in Fig.12, we observe roughly parallel trajectories. However, air cargo value has more pronounced upswings as a result of disruptions and tends to start the recovery just prior to the growth in total trade and GDP values (Kasarda & Green, 2005). Further studies showed that if the economy grows by 5%, air cargo demand grows by 7.5% and if the economy shrinks by 3%, air cargo demand falls by 4.5%, showing an elasticity greater than 1.5 (Lo et al., 2015).

However, the most important predictor of future demand is pricing which is directly influenced by jet fuel pricing. As fuel consumption makes up the largest part of the airline's operating cost, roughly 30% in 2012 numbers, the fluctuations in crude oil prices represent an immense challenge for the profitability of air freight. From 2000 to 2008, jet fuel prices increased by over 200% followed by a 50% decline in 2009 and then increasing again to 2008 level in 2010 and falling again in 2015. These fluctuations are predicted to continue in the next two decades (Wen et al., 2020). Demand analysis based on fluctuations in oil prices has proven that an increase in the price of oil leads to an increase in air freight yield (air freight transport cost) which consequently leads to a decrease in the demand for air freight shipping. This influence when modelled shows an elasticity of -0.14 to -0.19 (Kupfer et al., 2017). In other words, a 1 percent increase in oil prices leads to a 0.14 t 0.19 percent drop in air freight shipping. This suggests that demand in inelastic to the variation in price (Lo et al., 2015).

When compared to other modes of transport, air freight is 4–5 times more expensive than road transport and 12–16 times more expensive than sea freight, with air freight typically ranging between $1.50 to $4.50 per kg (Budd & Ison, 2017). However, there is no clear shift in demand from air to sea shipping based on the changes in air freight cost. Past correlations between the increase in demand for sea freight, and the decrease in demand for air freight is due to an increase in trade in goods that are more likely to be shipped by sea (raw materials and bulk goods) and a decrease in the demand of products that are more commonly shipped by air (high tech and fashion) (Kupfer et al., 2017)

In addition, the high monetary value and time-sensitive nature of the goods usually shipped by air make the switch to sea freight less feasible. An increase in air freight costs represents a small percentage of the total value of goods shipped, this makes air freight especially attractive for shipping high value to weight commodities and time-sensitive goods (Budd & Ison, 2017).

2.4. Air Connectivity

Cargo prices are one of the determining factors in air connectivity. According to the ICAO (ICAO, 2013b), air connectivity is defined as the ability to move across a network seamlessly based on the number of connections and the cost of this mobility.

The proven strong connection between air transport and economic growth discussed above highlights the direct benefits the aviation industry brings. It encourages the opening up of the skies and the increasing connectivity of many airports and cities (Cheung et al., 2020). The number of unique city-pair connections was over 18,400 in 2016 representing a 4% increase compared to the previous year and almost double what it was twenty years ago (IATA, 2017). These pairs are an important component of connectivity measures and show a strong correlation with the trade occurring in global value chains. This means that air connectivity indexes are a strong predictor of the competitiveness of a certain market in the global value chain (Arvis, Shepherd, 2013).

The growth in the air transport network and the increasing complexity of hub-and-spoke network models made measuring this connectivity a valuable indicator. Such indicators help airlines and airports know their competitive position and establish a benchmark against competitors, they also help policy makers evaluate travel times to other trade partners. And finally, it is a good indicator of route choice, in addition to ticket prices (Burghouwt & Redondi, 2013).

Different measures were put in place to quantify air connectivity, the best known being the World Bank Air Connectivity Index. This indicator defines connectivity as the role a country plays as a node within the greater network of global air transport. It is based on the pull a country's network exerts on the global network and the cost of moving to other countries (Arvis & Shepherd, 2016).

Another commonly used air connectivity measure is the IATA Air Connectivity Index (ACI). It measures the degree to which air transport contributes to economic development and productivity levels by taking into consideration different contributing factors including travel time, cost, number of connections and destinations, frequency, and reliability of service. IATA's ACI is adjusted relative to population and economic size to allow for a more objective valuation of the impact on economic growth (IATA, 2020a).

A third ACI measure was established by Airports Council International Europe as an indicator of regional accessibility and development. The council's measure shows a direct relation between air connectivity and economic development, as a 10% increase in direct air connectivity comes with 0.5% increase in GDP per capita. This ACI is based on the access to direct and indirect connections based on the number of destinations, frequency of service and the quality of the connections. As a result, 3 distinct measures are adopted: direct connectivity for direct air services, indirect connectivity based on connections and finally airport connectivity, which is a more comprehensive measure reflecting both direct and indirect connectivity (Airports Council International, Europe, 2019).

A comparison of the three air connectivity measures discussed above, and their different approaches are summarized in Table 3.

Institution	IATA	ACI Europe (NetScan)	World Bank
Definition	Air connectivity is a measure which reflects the scope of access between a country and the global air transport network. The IATA measure captures the range and economic importance of destinations, and the number of onward connections available through each country's aviation network.	Air connectivity is a composite measure reflecting the number of destinations, the frequency of service and the quality of the connections at a given airport. The NetScan connectivity measure (used by ACI Europe) reports airport connectivity using direct, indirect, total and hub connectivity.	Air connectivity refers to a country's ability to effectively connect to other nodes within a particular network. Rooted in a general gravity model framework, the World Bank measure reflects the degree of air connectivity between a country and its neighbours as well as the interactions among other countries in the global air transport network.
Coverage	Global	Europe	Global
Node	City, country, region	Airport, country	Country
Metric	Destination- weighted outbound seats 0 to infinity	Composite non-dimensional number 0 to infinity	Non-dimensional number 0 to 1
Characteristics	- Global coverage - Intuitive and easy to use - Adaptable to examine total, international or intra-regional connectivity - Versatile: weighted by GDP or population - Updated regularly - Captures indirect and indirect connectivity implicitly - Does not capture connecting time and re-routing explicitly.	- Limited coverage (Europe and selected other airports) - Airport focused - Updated regularly - Captures indirect and hub connectivity explicitly - Captures the quality of indirect connections (time and re-routing)	- Global coverage - Theoretically sophisticated and robust (based on a network analysis framework) - Computationally complex - Difficult to adapt and update (last available index is for 2007) - Sensitive to input parameters (sensitive to changes in the gravity coefficient)

Table 3. A Comparison of different approaches to measuring air connectivity

Source: (IATA, 2020a)

2.5. Impact of Capacity on Air Cargo Prices

Pricing changes continuously affect the dynamics between the different players in the air cargo industry. Pricing and bookings vary according to long- or short-term contracts, available capacity, competition, etc. The pricing is determined according to a common practice called revenue management, also known as yield management. Revenue management is a common practice in the airline industry and it is defined as managing price and inventory to maximize profitability (Kasilingam, 1997). The fundamentals of revenue management can also be applied to cargo transportation, with differences because of how capacity is generated. As opposed to passenger capacity which is defined by the number of available seats, the capacity for cargo can be affected by many factors such as weather, payload, etc. (Huang & Hsu, n.d.). Accounting for cargo capacity is also more complicated because freight is 3 dimensional, with weight, volume, position and number of containers as variables (Kasilingam, 1997).

According to Kupfer (Kupfer et al., 2017), following periods of overcapacity, we see yield prices decrease to encourage more bookings and avoid flying aircraft with empty cargo space. Inversely, an increase in demand results in a shortage of freight capacity which leads to an overall increase in yields. Morrell (Morrell, 2012) argues that balancing yields and capacity is the number one challenge in the air freight industry, as belly capacity from passenger aircraft cannot be removed from the market when demand and international trade decline, resulting in low and unprofitable rates. This is not the case for freighter capacity as airlines often choose to take freighter aircraft out of service to control capacity and yield, like Lufthansa and Cathay Pacific did following the slump in demand after the 2008 financial crisis. The opposite also holds, when capacity is reduced and demand picks up, rates go up rapidly, but often not as fast as the rate at which capacity can be brought back up. In the air freight industry, capacity does heighten the upward and downward trends in yields (Morrell, 2012).

In summary, previous research has studied the changes of air freight pricing in relation to demand, economic growth, air connectivity and capacity changes. This paper will study the impact of these same factors on the air freight price changes in the context of the COVID-19 pandemic.

3. COVID-19 and its Implications for the Aviation Industry

3.1. COVID-19 Government Policies and Travel Restrictions

The response to the COVID-19 crisis, when it comes to sector- or firm-specific measures, has so far heavily targeted the air transportation industry (OECD, 2020). Different policies have affected aviation differently in different regions, but all sources agree that the aviation industry was impacted globally irrespective of the region (ICAO, 2021c).

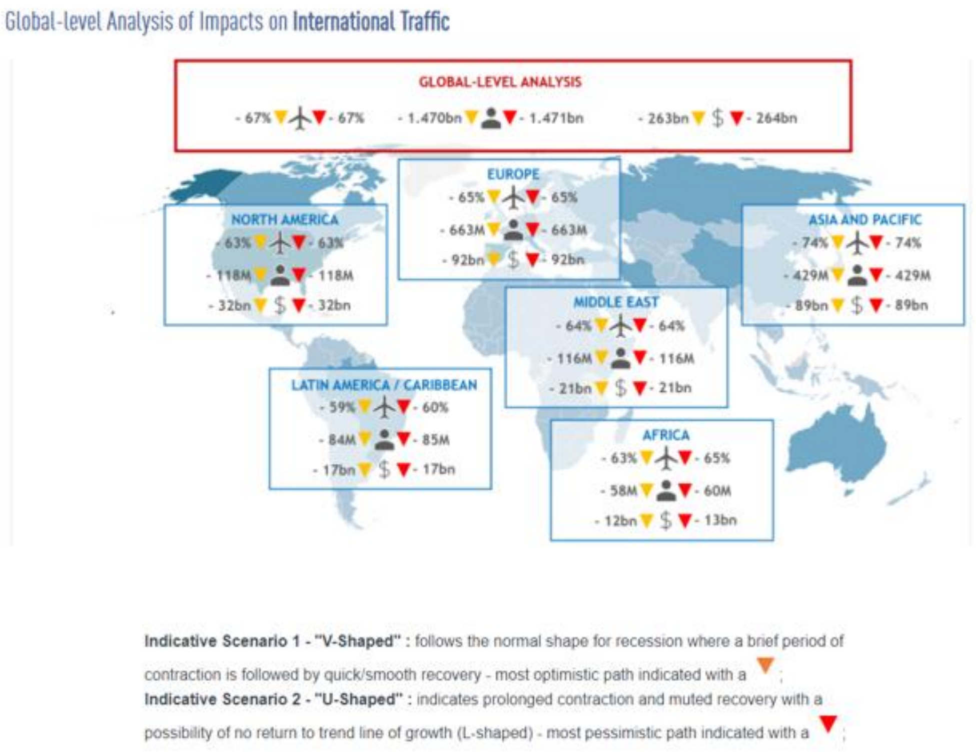


Fig. 13. *Global level analysis of the impact of COVID-19 on international traffic*

Source: (ICAO, 2021c)

Travel restrictions following the spread of the coronavirus included enhanced screenings, health certificates requirements, quarantines, passengers of specific nationalities or arriving from specific countries being denied entry, and even complete closure of borders in some countries, except to their own nationals. By April 2020, these various types of mobility restrictions had nearly completely shut down international travel. Markets with the toughest restrictions represented 98% of global air traffic (IATA, 2020b).

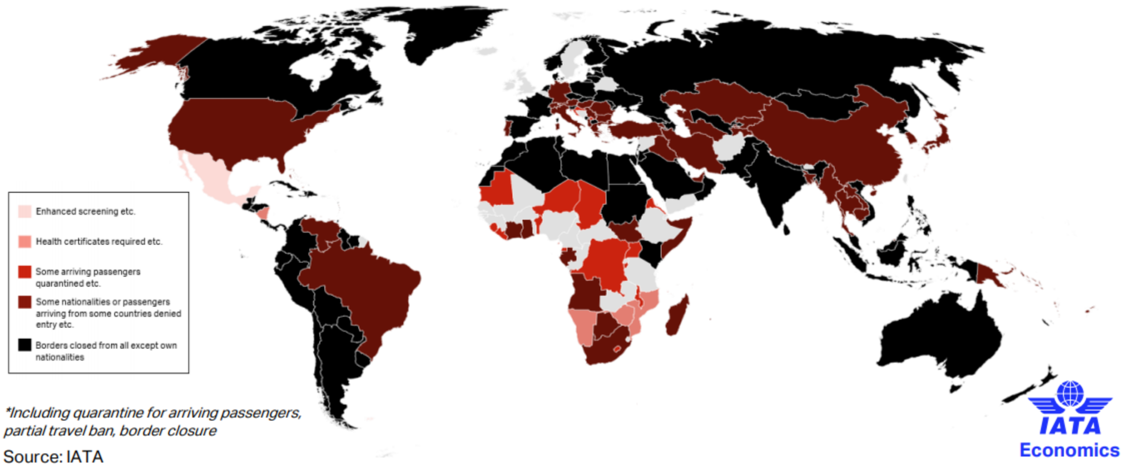


Fig. 14. *Global travel restrictions by country for March 2020*

Source: (IATA, 2020b)

3.2. Impact on Air Connectivity

Global travel restrictions took place at a historically unprecedented level following the COVID-19 outbreak. This resulted in the aviation industry being one of the most affected by the pandemic. Sun, Wandelt and Zhang (Sun et al., 2020) compared origin and destination pairs before and during the pandemic and concluded that travel restrictions had about a two months' delay compared to the severity of the outbreak and that these restrictions affected mostly long-distance international flights. To be exact each airport lost on average 50% of its connections.

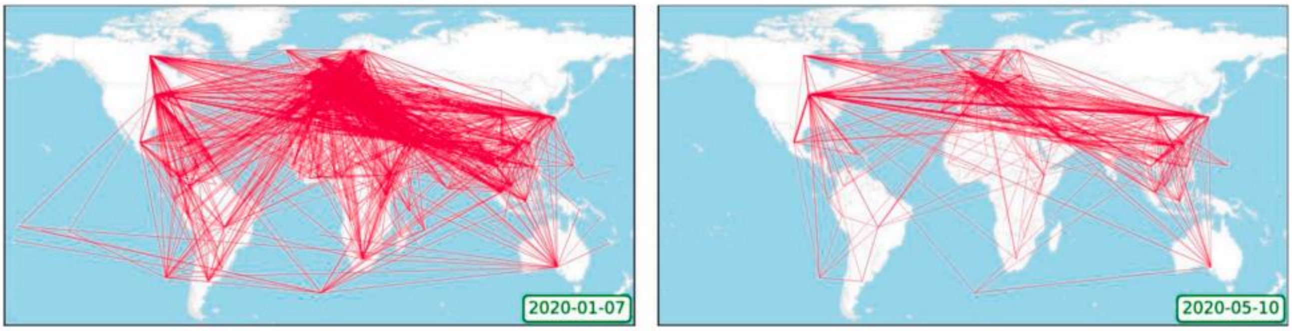


Fig. 15. *International direct flights between country nodes in January vs. May 2020*

Source: (Sun et al., 2020)

The International Air Transport Association also looked at the impact of COVID-19 on air connectivity and concluded that domestic markets were more resilient and were expected to recover faster than international air travel. The most significantly impacted regions are Africa and Europe, followed closely by Latin America and the Middle East. On the other hand, the two most connected regions in the world, Asia-Pacific and North America were less impacted in part thanks to the ongoing domestic traffic (IATA, 2020a).

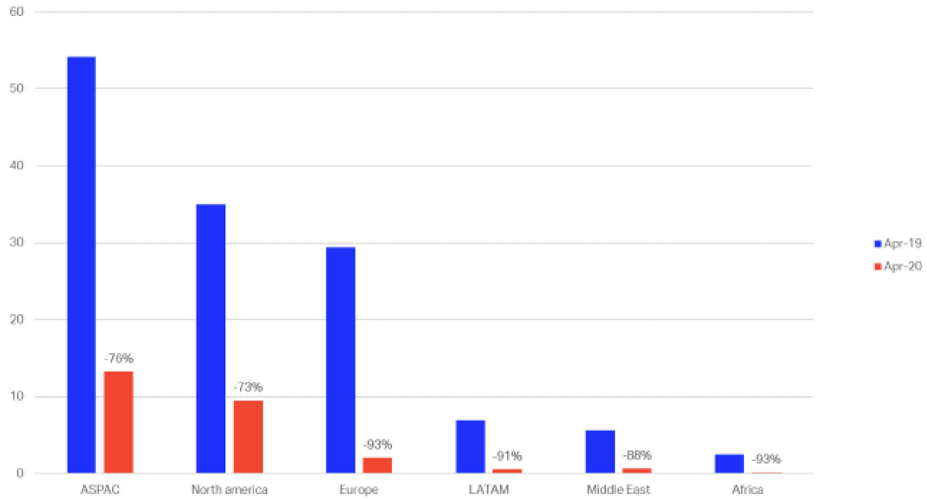


Fig. 16. *Disruptions to air connectivity by region. April 2019 vs 2020*

Source: (IATA, 2020a)

Looking at the topmost connected countries in the world, China, the United States, and Japan were less impacted because they maintained their domestic flights even during the peak of the pandemic. India, on the other hand, suspended domestic flights for two months and Germany had a nationwide lockdown leading their air connectivity to evaporate during that period (IATA, 2020a).

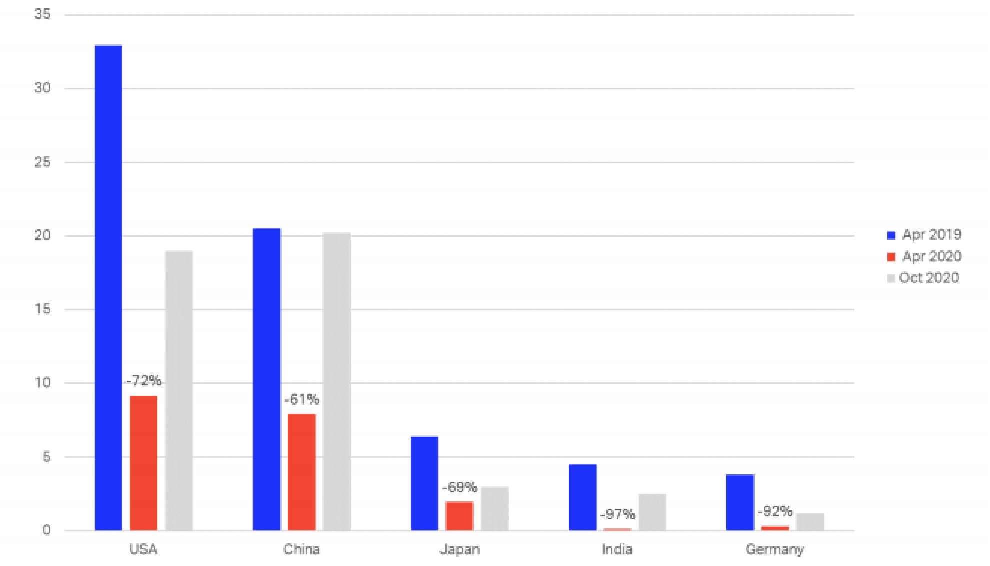


Fig. 17. *Disruptions to air connectivity in the 5 most connected countries in the world*

Source: (IATA, 2020a)

3.3. Airlines Reaction Plan

The travel bans, increasing restrictions and the sudden decrease in demand threatened the survival of many airlines and drove many to bankruptcy (Maneenop & Kotcharin, 2020). As a reaction, airlines had to put in place immediate plans to reduce their costs. Albers and Rundshagen (Albers & Rundshagen, 2020) analyzed the reaction of European airlines to this shock in the airline industry and categorized the response into retrenchment, preserving, innovation, exit and resume.

Retrenchment included both short term and long-term strategies. The short-term strategies included fleet grounding, job cuts, and reduced flight frequencies. Long-term strategies included retiring certain airplane types, like the less fuel-efficient A-380 by Air France and Lufthansa, and cancelling aircraft orders, as done by EasyJet. Innovation included new joint ventures, new routes or cargo-focused strategies detailed further below. Some airlines had to resort to extreme strategies including filing for bankruptcy, like AtlasGlobal and Air Italy. Airlines then started planning for new routes for when operations would resume (Albers & Rundshagen, 2020).

Response category	Corresponding findings/airline prevalence
1) Retrenchment *Substantial cost/asset reduction*	*75 news items in total*
Short-term orientation	All European airlines grounded their fleets more or less completely due to the imposed travel restrictions. Almost all airlines announced job cuts and/ or reduced work patterns in accordance with the respective national policy schemes to maintain employment. → More or less all European airlines
Long-term orientation	• Air France (brings forward A-380 retirement; restructure domestic network with less flights and more LCC Transavia) • Austrian Airlines (reduce fleet by 25%, management by 30%) • Brussels Airlines (reduce fleet by 30%) • EasyJet (cancel aircraft orders, slim fleet) • Helvetic Airways (stopped growth strategy) • Lufthansa (deep cuts into future fleet, grounding A-380s probably permanently, reposition 20% smaller)
2) Persevering *Safeguarding status quo*	*37 news items in total*
Financial	Most European airlines have sought government aid through grants, loans at preferred conditions/state guarantees, or subsidies. → Most European airlines
Position	• Alitalia (Italy's plan to safeguard nationalized airline as springboard for relaunch of Italian economy; continue codeshare with Delta Air Lines) • Ryanair (committed to drive price competition after crisis)
3) Innovating *Strategic renewal*	*16 news items in total*
Crisis-specific	• Austrian (reconfiguring aircraft for cargo) • Icelandair (reconfiguring aircraft for cargo) • Lufthansa (LH Technik offers cargo conversion) • Sun Express (switch aircraft to freight operations) • Swiss (reconfiguring aircraft for cargo)
Longer term	• Aeroflot (plans to open Europe-Asia transfers) • Air France-KLM (transatlantic joint-venture with Delta Air Lines and Virgin Atlantic) • British Airways (UK-Australia joint venture with Qatar Airways) • IAG (remains committed to takeover of Air Europa) • Volotea (plans 40 new routes for summer) • Wizz Air (plans to enter new markets in Europe, increase scale of Abu Dhabi venture, intends to grow ancillary business)
4) Exit *Discontinuation of activities*	*11 news items in total*
Failure	• Air Italy (ceased operations) • AtlasGlobal Airlines (filed for bankruptcy) • Braathens (filed for court administration) • CityJet (entered local equivalent of Chapter 11) • Flybe (gone into administration) • Norwegian Air Shuttle (pilot and cabin crew subsidiaries filed for bankruptcy in Denmark and Sweden)
Withdrawals	• British Airways (could pull out of LGW permanently) • LOT (giving up bid for Condor) • Lufthansa (close Germanwings subsidiary) • Virgin Atlantic (exit base at LGW)
5) Resume	*9 news items in total* Airlines re-introduce flights and/or increase schedules for summer 2020 onwards, returning to (still considerably modified) flight operations at least on the continent.

Table 4. Airlines responses to the pandemic

Source: *(Albers & Rundshagen, 2020)*

At the peak of travel restrictions in early April, airlines pulled upwards of 70% of the global fleet out of service. Slowly and leading into the summer, about half of these airplanes were put back into service, but the global fleet was far from its pre-pandemic size; 19,200 aircraft versus 28,000 in early January before COVID-19 was declared a pandemic (Wyman, 2020).

Region	Pre-COVID fleet size	Aircraft sent to storage	Aircraft put back into service
Africa	1,137	700	262
Asia Pacific	8,689	5,334	3,618
Europe	6,821	5,414	2,871
Latin America & Caribbean	1,746	1,319	469
Middle East	1,404	1,059	504
North America	8,087	4,588	2,092
Total	**27,884**	**18,414**	**9,816**

Table 5. In service and in storage fleet breakdown for 2020

Source: *(Oliver Wyman, 2020)*

With over 50% of cargo being carried in the belly of passenger airplanes, and with the continuous demand especially for PPE (Personal Protective Equipment) during the early months of the pandemic, the air transport industry witnessed an unprecedented shortage of cargo capacity. This situation pushed the airlines to get creative with their cargo transportation and implement new changes. This initially started with airlines like Cathay Pacific, Korean Air and Scoot using their passenger aircraft to transport cargo only. Later, other airlines joined this trend including United Airlines that flew 40 passenger aircraft weekly carrying cargo only. The next adjustment came when airlines started maximizing the cargo hold by placing boxes on passenger seats and in overhead bins, which was done for example by Austrian airlines. One of the most extreme solutions was converting passenger aircraft to quasi-freighters by taking out the seats. Several airlines adopted this solution, including Greece’s Aegean Airlines, China Eastern Airlines and other airlines that do not usually operate freighter aircraft, like Air Canada and Air New Zealand. This allowed airlines with no freighters in their fleets, like Air New Zealand, to fly 14 cargo-only flights to Shanghai during the week of April 20th (Forbes, 2020b).

This passenger to freighter conversion (P2F) was an extremely innovative and unusual tactic, as historically P2F only occurred in older and less efficient aircraft that had been retired from passenger service. In addition, the P2F conversion requires extensive work including main deck strengthening, removal of windows, creating large side cargo doors, etc. This P2F conversion has historically been limited to a small number of licensed companies due to its complexity (Budd & Ison, 2017). This process that historically would have taken months was being implemented by airlines that had never done it before in the matter of weeks or days, like was the case of Air Canada.

American Airlines used a 777-300ER to carry only cargo between Dallas and Frankfurt AMERICAN AIRLINES

Air Canada is removing all economy and premium economy seats on three 777-300ER aircraft. AIR CANADA

Austrian Airlines 777-200 being loaded with cargo in the passenger cabin. AUSTRIAN AIRLINES

Restraint nets will secure cargo in Air Canada's cabin AIR CANADA

Source: (Forbes, 2020b)

The urgent and extreme need for medical supplies and PPE also drove several airlines to set flights to destinations they did not previously serve for the sole purpose of carrying this urgent cargo. For example, Austrian airlines do not usually fly to Xiamen, but special flights were set up to pick up medical supplies. Aer Lingus also flew up to four times per day from Dublin to Beijing for urgent PPE supplies despite them never flying to anywhere in Asia before (Forbes, 2020a).

Other creative measures put in place by the industry to mitigate the sudden decrease in capacity and increase in air cargo demand included flying test aircraft, like the Airbus A330-800, from Toulouse to Tianjin to pick up over two million face masks.

Exceptionally, Airbus also dispatched its A400M, a multipurpose military transport aircraft, to carry masks to Spain for both testing and demonstration purposes. The last of Airbus's unique flights included sending the Dreamlifter for relief missions. The Dreamlifter is not usually used to carry cargo but it is built to transport oversize cargo that usual freighters cannot carry such as aircraft parts. (Forbes, 2020a)

Airbus A330-800 used to ferry medical supplies from Tianjin to Toulouse AIRBUS

Airbus A400M transports masks to Spain in support of COVID-19 crisis efforts AIRBUS

An employee stands in front of the Boeing Co. 747 Dreamlifter, used for transporting large pieces of ... [+] BLOOMBERG NEWS

Source: (Forbes, 2020a)

3.4. Air Freight Capacity Evolution After COVID-19 Outbreak

According to Flight Radar, the number of commercial flights decreased by 41.7% in 2020 compared to 2019, with the lowest numbers being recorded in mid-April with a slight recovery in mid-August before slowing down again (Flightradar24, 2021). The recovery seems to have slowed down after September in the light of the second and third waves and of fears of the new strains of COVID-19 announced in the United Kingdom and South Africa. November and December saw a slight increase and signs of recovery that could have been the results of news concerning the approvals for various vaccines, notably in the United Kingdom, the USA, Canada and the European Union. (Dube et al., 2021)

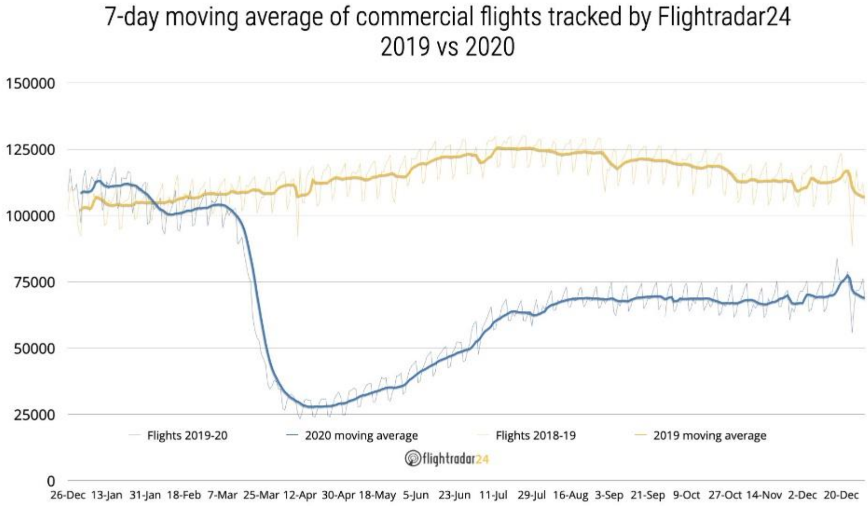


Fig. 18. *7-day moving average of commercial flights. 2019 vs 2020*

Source: (Flightradar24, 2021)

At the peak of travel restrictions in April 2020, airlines pulled upwards of 70% of the global fleet out of service (Wyman, 2020) as shown in Table 5 in section 3.3. This caused a drastic reduction to the availability of belly freight capacity from passenger airplanes.

The decrease in number of commercial flights resulted in a global decrease in the available cargo capacity from using the belly of passenger aircraft. Looking at the capacity breakdown for the top 8 airports in the world, we notice that the Chinese airports, including Shanghai Pudong airport (PVG), Beijing Capital airport (PEK), and Guangzhou Baiyun airport (CAN), were the first to be affected in February and started their recovery around the end of March. Other Asian airports like Narita International Airport (NRT), Hong Kong International Airport (HKG), and Incheon Airport (ICN) saw their decline start towards the beginning of March and had only recovered very slightly by April. Other international airports and the global average plummeted by the end of March (Fig. 19).

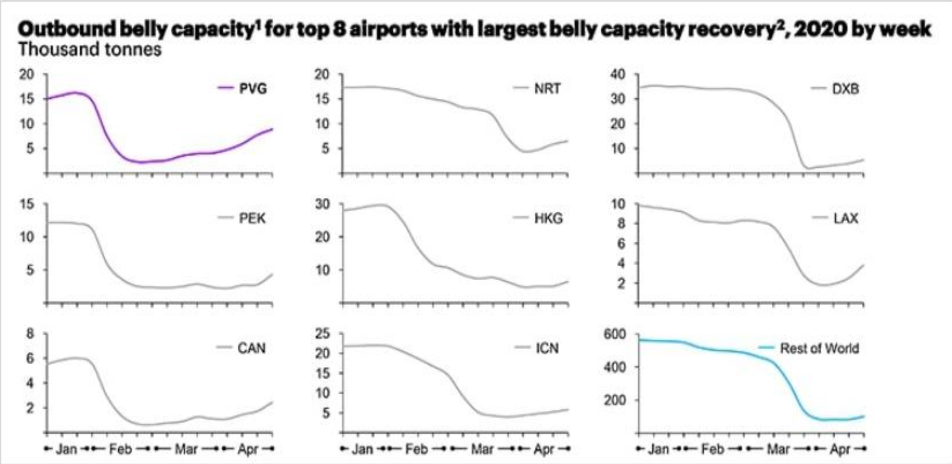


Fig. 19. *Outbound belly freight capacity in top 8 airports. January to April 2020*

Source: (STAT TIMES, 2020b)

With over 50% of global air freight being carried in passenger aircraft, the unprecedented decrease in scheduled passenger flights caused major disruption to the cargo supply chain (Flightradar24, 2020). As a result, the need for extra freight capacity increased. Airline reacted to this by increasing cargo-only flights using passenger aircraft leading to an increase of over 35% of the number of cargo flights compared to April 2019. (ICAO, 2021c)

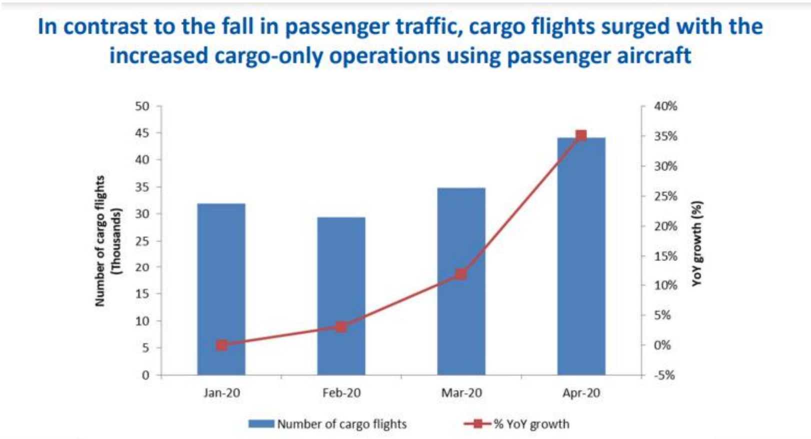


Fig. 20. *YOY growth in cargo flights, 2019 vs 2020*

Source: *(ICAO, 2021c)*

According to Stat times (Fig. 21), the decrease in passenger belly capacity by over 78% in the month of April resulted in an increase of 20% in airline freighter capacity and 16% increase in integrator freight capacity.

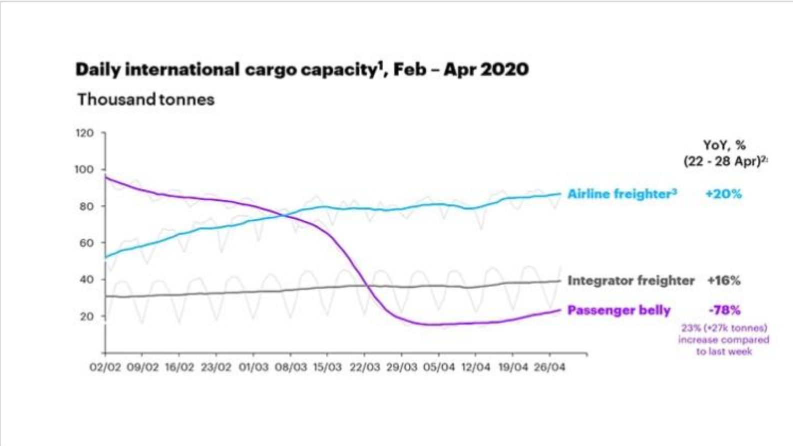


Fig. 21. *Daily international cargo capacity- February to April 2020*

Source: (STAT TIMES, 2020b)

The decrease in freighter versus belly cargo capacity was not the same in all regions. Looking at the breakdown comparing March 2020 to 2019, the largest loss of belly freight share seems to be in the Europe to North America route followed by intra-Asia traffic.

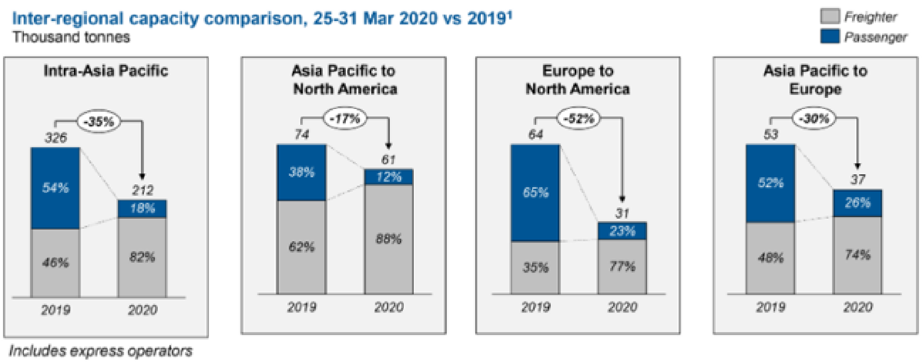


Fig. 22. *Inter-regional capacity comparison 2020 vs 2019*

Source: (STAT TIMES, 2020a)

Despite the increase of cargo-only flights, the decline in international capacity, including both all freighters and widebody belly aircraft, far surpassed the decrease in air trade (Fig. 23.) causing a large supply and demand imbalance that further affected pricing.

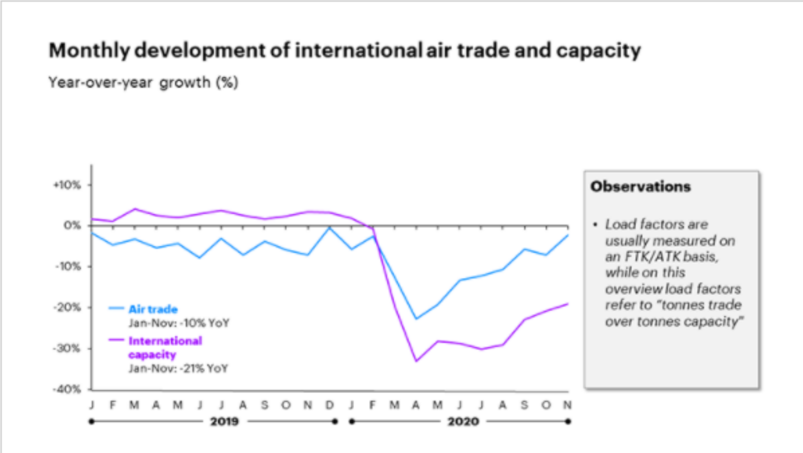


Fig. 23. *Monthly YOY growth of international trade and capacity*

Source: (STAT TIMES, 2021)

According to the ICAO, active fleets of all types of aircraft decreased in numbers by anywhere from 45% to 60%, except for the number of cargo freighters in service which increased by 4% in 2020 compared to 2019 (ICAO, 2021a)

Table 6. Active fleet by aircraft types 2020 vs 2019

Source: *(ICAO, 2021a)*

The number of flights itself for cargo-only freighters increased by over 6.5% globally, with December witnessing the highest increase by about 20%. The regions with the highest annual increase are Asia-Pacific and North America with 9.2% and 8.8% increases, respectively (ICAO, 2021b)

Operational Impact on Air Transport

Flights among Months Including Cargo - International

Data Source: ICAO and ADS-B Flightaware

Flights | International | Cargo

Region of Origin	Click to Drill (States / Territories)	2019	2020	Difference	% Difference
AFRICA	AFRICA	8,997	7,132	-1,865	-20.73%
MIDDLE EAST	MIDDLE EAST	23,977	24,854	877	3.66%
LATIN AMERICA/CARIBBEAN	LATIN AMERICA/CARIBBEAN	42,493	43,860	1,367	3.22%
NORTH AMERICA	NORTH AMERICA	68,658	74,697	6,039	8.80%
EUROPE	EUROPE	131,503	140,032	8,529	6.49%
ASIA/PACIFIC	ASIA/PACIFIC	119,167	130,078	10,911	9.16%
Grand Total		394,795	420,653	25,858	6.55%

Table 7. International cargo flights by region 2019 vs 2020

Source: (ICAO, 2021b)

The increase in cargo capacity, especially at the end of 2020, was primarily driven by the increased demand created by the distribution of medicine and PPE (Forbes, 2020a). In addition, the aviation industry was considered crucial in the distribution of the vaccines which started being approved by several countries at the beginning of December. This is expected to increase cargo capacity demand further in 2021 as the needs for temperature-controlled shipments and for fast delivery can only be met through air transport (Dube et al., 2021). This is reflected in the significant recovery seen in CTK (Capacity Tonne-Kilometers), especially in the last two quarters of 2020.

	Industry wide CTKs	North America-Asia	Asia-Europe	Europe- North America	Within Asia International	Global Container throughput
1st Quarter	-16.9	-5.8	-17.9	-20.2	-15.8	-4.9
2nd Quarter	-1.1	7	-4.8	-18.1	-16.5	3
3rd Quarter	0.2	2	1.7	1.3	1.4	2.5
4th Quarter	7.2	2.9	3.4	19.1	8.9	7.5

Fig. 24. *Quarterly change of CTKs in 2020*

Source: *(Dube et al., 2021)*

	Industry wide CTKs	North America-Asia	Asia-Europe	Europe- North America	Within Asia International	Global Container throughput
1st Quarter	-15.3	-5.2	-18.9	-20.1	-16.7	-5.9
2nd Quarter	-16.6	1.7	-21.5	-34.7	-32.3	-4.8
3rd Quarter	4	-3.2	-1.8	-4.1	-6.5	2.5
4th Qquarter	-8.6	4.2	-17	-20.3	-23.7	3.3

Fig. 25. *Annual change of CTKs in 2020 vs 2019*

Source: (Dube et al., 2021)

Against all odds, demand for air cargo capacity recorded its first positive weekly year-over-year growth in 12 months during the holiday's week of December 28th to January 3rd. This narrowed the monthly year-over-year change in demand to its lowest value in 2020 at -5% (Lloyd's Loading List, 2021)

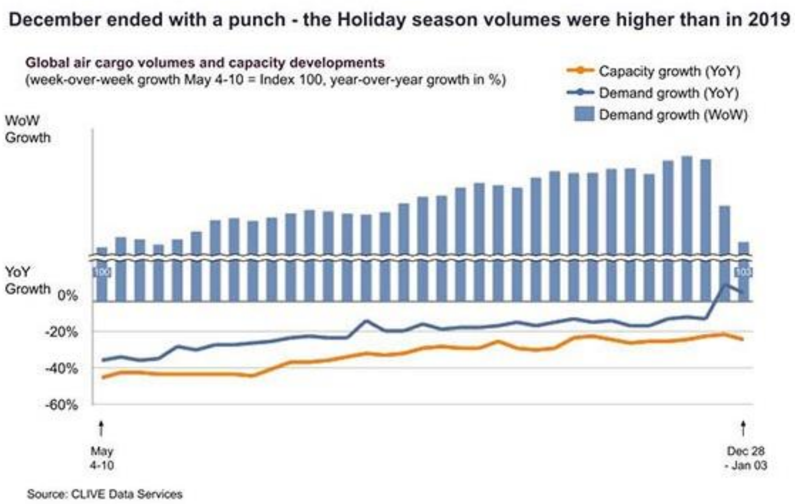


Fig. 26. *Week over week growth in air cargo volumes 2020*

Source: *(Lloyd's Loading List, 2021)*

The end of the year saw belly passenger capacity greatly increase, by over 160% compared to the peak drop in April, but remain at -61% versus the same period last year. The express freighters and airline freighters continued their increase and operated with 27% and 33% increases respectively compared to December 2019 numbers. (Fig. 27)

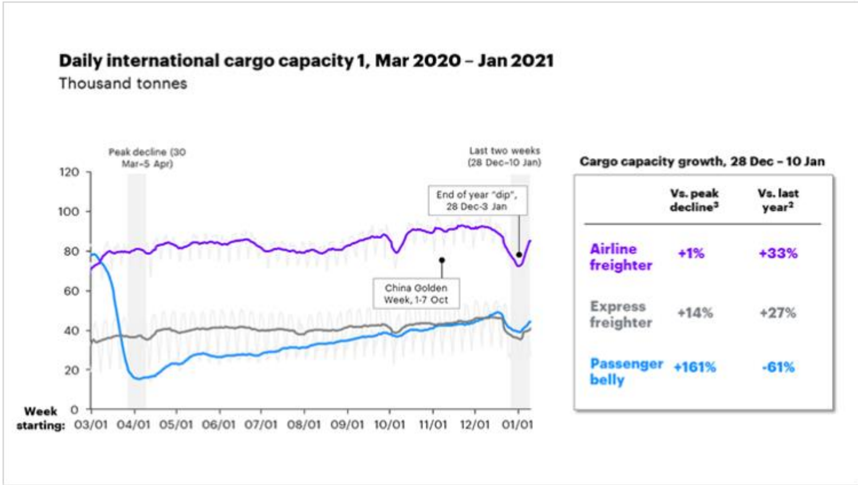


Fig. 27. *Daily international cargo capacity, March 2020 to January 2021*

Source: (STAT TIMES, 2021)

4. Data and Methods

4.1. Air Cargo Volumes and Yield Data (CASS)

In our aim to analyze how COVID-19 impacted air freight pricing and what the factors were behind these impacts, we will make use of an exclusive data set on air cargo pricing that is only accessible through premium subscriptions. However, we were thankfully granted exclusive permission from the International Air Transport Association (IATA) to use the air freight pricing data from the CargoIS Business intelligence product. This access was granted exclusively as I was previously employed within the CargoIS team and it is contingent on a Non-Disclosure Agreement that limits its use to market average pricing only, and on the condition that only the findings are published and not the data itself.

This product offers actionable data collected through CASS (Cargo Accounts Settlement System) managed by the IATA. The CASS is the payment processing system between airlines and freight forwarders that allows monthly payment transactions for all shipments that took place the previous month. Since this is transactional data, the prices extracted through the CASS are the most accurate in the industry. The CASS is used in over 100 countries worldwide, however, due to legal restrictions, only the data from 73 countries was made available (Appendix1).

The data can be aggregated at the country, city, and airport level. The data covers the period from January 2016 to December 2020 and provides the following detailed information:

- Shipment year
- Shipment month
- Destination Country
- Destination City

- Origin country
- Origin city
- Origin airport
- Destination Airport
- Shipment weight
- Rate per kg

The rates provided by CargoIS are market average on the trade lane down to the airport-to-airport level. The charges and yield per kilogram are based on weight charges only. It excludes fuel surcharge, security fees, handling fees, etc. Unfortunately, the commodity detail is not available which makes the analysis by type of product not possible. A sample of the data is provided in Appendix2.

4.2. Regression Analysis

To understand the impact of COVID-19 on air freight prices and the drivers behind the yield changes, we will use a regression analysis to find which factors influenced air cargo prices during the pandemic. The analysis will compare the data from the 2020 period to the data from 2019. We will run a multiple linear regression to evaluate the fluctuation of the year-over-year monthly yields and whether it can be explained by the changes in capacity, the ACI, the prevalence of COVID-19 and government travel restrictions. We will use the following regression model:

$$Y_{i,t} = \alpha + \beta_0\, Cap_{i,t} + \beta_1\, MktW_{i,t-1} + \beta_2\, ACI_i + \beta_3\, Covid_{i,t} + \beta_4\, TR_{i,t} + \varepsilon_{i,t}$$

- $Y_{i,t}$: Percentage change in yield/price for airport/country *i* in month *t*
- $Cap_{i,t}$: Percentage change in capacity (number of flights) for airport/country *i* in month *t*

- $MktW_{i,t-1}$: Market weight known as volume transported out of airport/country i in month t-1 *(2019 data)*
- ACI_i: Air Connectivity Index for airport/country i (2019 data)
- $Covid_{i,t}$: number of new COVID cases per million for airport/country i in month t
- $TR_{i,t}$: the level of government travel restrictions for airport/country i in month t
- $\varepsilon_{i,t}$: Standard error

Dependent Variable: Year-Over-Year Percentage Change in Freight Yield

Relying on the CASS database, we will evaluate the percentage changes in the prices of air freight in 2020 compared to the same months in 2019. All rates are provided in USD/kg and will be evaluated both at the country level for the whole data set and then at the airport level for major European airports. The yield used for our percentage change calculations is the average monthly yield based on the origin of the shipment. The change in yield is denoted as $Y_{i\ t}$ for airport or country i during month t.

Independent Variable 1: Percentage Change in Capacity

Relying on the CASS database, we will use capacity data as the main independent variable of interest for the analysis of yield/price changes. We can only study this relation in the subsample of European airports and countries since capacity data are not available globally. The number of commercial flights is used as a proxy and is aggregated by month. The change in capacity is denoted as $Cap_{i\ t}$ for airport or country i during month t.

Control Variables:

Market weight transported

The first control variable we will use is the weight transported in 2019 by market, which we obtained from the CASS database. This is used to denote the size of the airport/country size and the market demand. 2019 volumes are used instead of 2020 to avoid possible impacts of the COVID-19 pandemic on demand.

Air Connectivity Index

Air connectivity indexes are used to evaluate the impact of high and low connectivity on the change in freight yield. They will be applied to both at the country and airport level. At country level, we use the IATA ACI (IATA, 2020a) and for the airport level, we use the Airport Council Europe ACI (Airports Council International, Europe, 2019). The ACI is denoted as ACI_i for country or airport *i*. The value is annual so there is no monthly variation.

Prevalence of COVID-19

To evaluate the response to the spread of the pandemic, we will use the number of COVID cases per million population as reported by John Hopkins University (John Hopkins, 2021). The original data is available daily but for the purpose of our analysis, we will use monthly numbers. The data is also available at the country level only, therefore for airports, we will use the corresponding country statistics. The number of COVID cases is denoted as $Covid_{i\,t}$ for country *i* during month *t*.

Government travel restrictions

Travel bans and restrictions reflect the severity of government policies because of the pandemic. The Oxford COVID Government Response Index will be used to measure these policies. Data is available daily but was grouped monthly for the purpose of consistency with the rest of the variables. The level of travel restrictions is denoted as $TR_{i\,t}$ for country *i* during month *t*.

5. Results and Findings

Our results section consists of three parts. We start off with a comprehensive descriptive analysis of the CASS data during the COVID-19 pandemic to identify impactful facts related to air cargo prices and air cargo capacity across the globe. Next, we will investigate correlations between key variables of interest. Finally, we will present the results of the econometric analysis.

5.1. Descriptive Analysis of Air Cargo Trends

2016 to 2020 Data Trends

Air cargo capacity has witnessed continuous growth in demand as shown in the figure below, with 2017 and 2018 especially witnessing incredible year-over-year increases of 12.04% and 3.8% respectively. 2019 was a slower than usual year with a decrease of -4.1% but still with promising results which were above the 2016 level. However, 2020, despite starting strong in January and having the usual Chinese New Year annual dip in February, continued to plummet, reaching the lowest recorded level of weight transported in April.

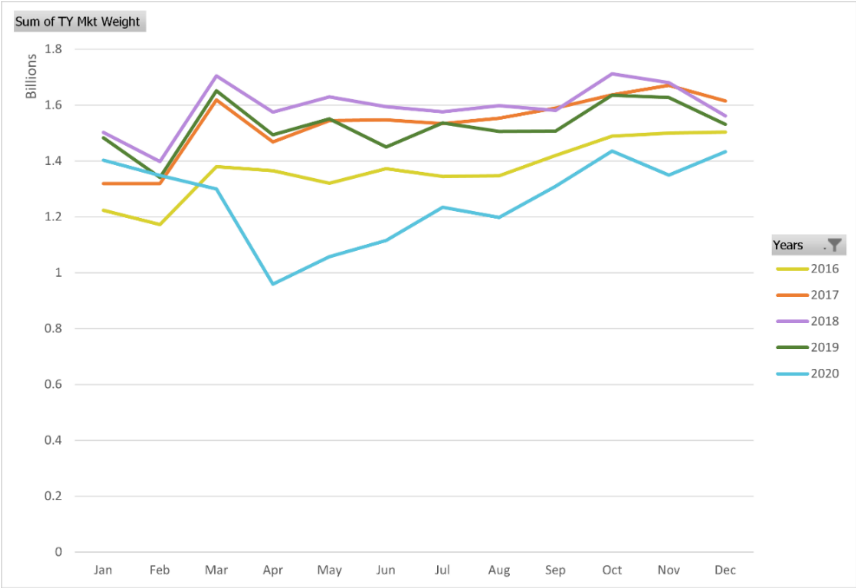


Fig. 28. *Cargo weight transported, 2016 to 2020.*

Source: *CASS data, calculated by author*

Despite considerably lower volumes being transported in 2020, the graph below shows that the revenues generated by air cargo ranged from 1.5 to 2 times higher than 2019 reaching a peak of almost 4 billion dollars globally in November 2020.

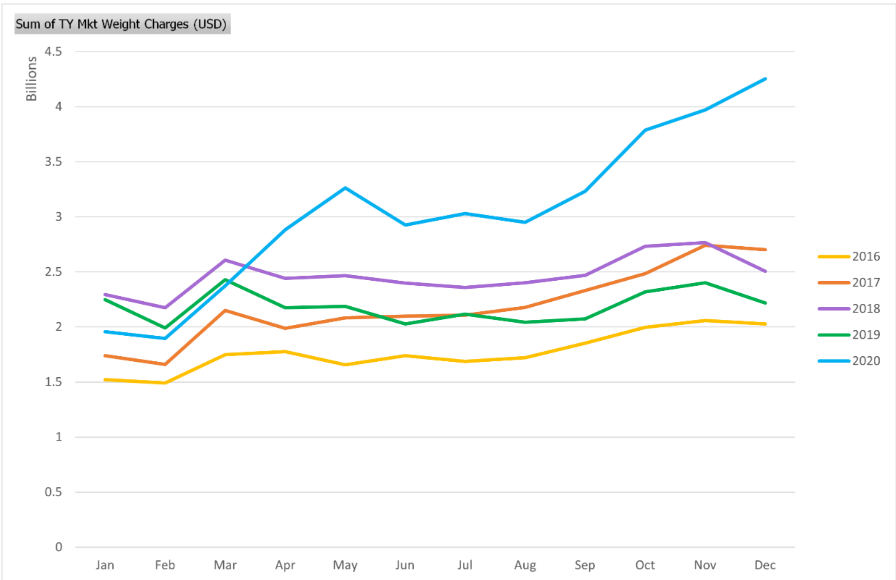


Fig. 29. *Cargo freight revenue, 2016 to 2020.*

Source: *CASS data, calculated by author*

Record low volumes and record high revenues are a very unusual combination that can only be explained by large increases in rates per kg. The graph below compares the average rate per kg globally from 2016 to 2020. The graph clearly shows comparable rates from 2016 to 2019. 2020 also started with average rates that skyrocketed starting mid-March and persisted in a range of 1.5 to 2 times higher than average rates throughout the year.

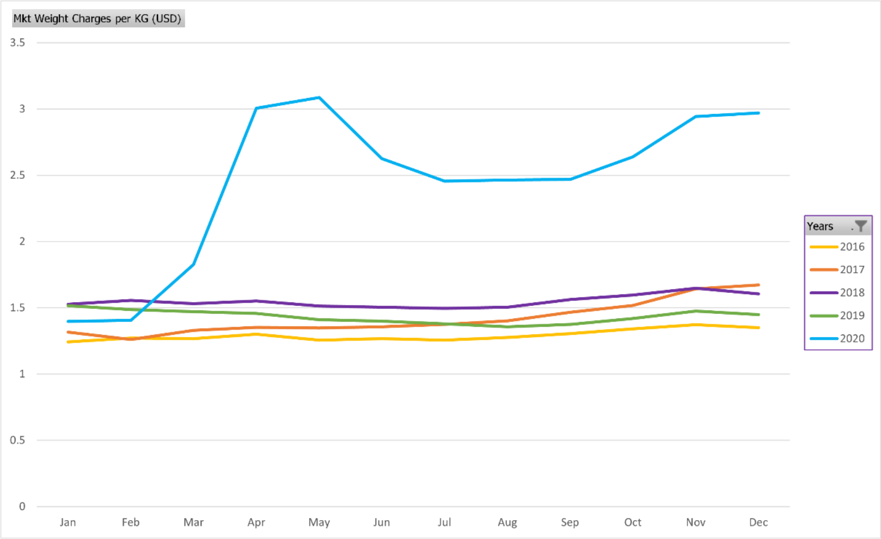


Fig. 30. *Weight charges per kg, 2016 to 2020.*

Source: *CASS data, calculated by author*

2020 vs 2019 Trends

To understand the impact of the pandemic, we will be looking at the variations in the volume of air freight transported as well as the variation in air freight charges per kg, and then compare the 2020 values to the 2019 values.

Total Volume Transported 2019 vs 2020.

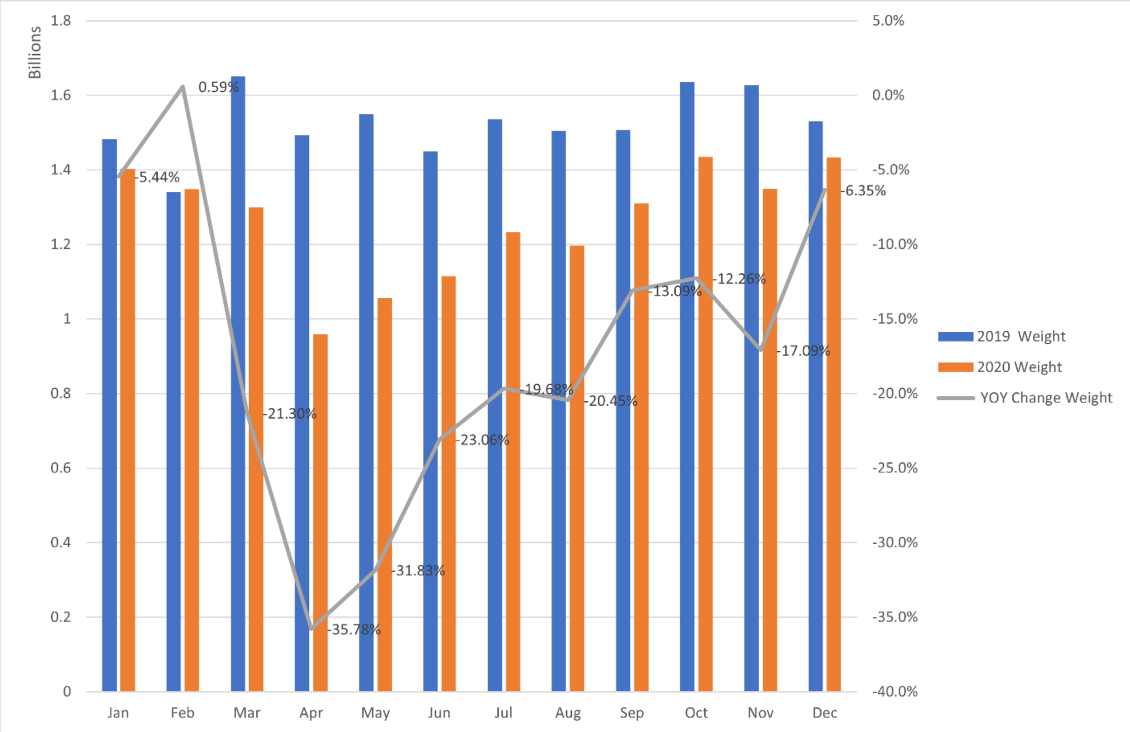


Fig. 31. *Total volume transported 2019 vs 2020.*

Source: *CASS data, calculated by author*

Looking at the monthly breakdown comparison between 2019 and 2020, we see that the volume transported in January and February was similar to the numbers from 2019. However, the numbers started decreasing in March to hit a record low in April representing a difference of -35.7% compared to the previous year. A dip of over 20% continued until the month of September where we see a slight recovery to have a limited year-over-year decline ranging from -12% in September to -17% in November.

December showed the lowest year-over-year monthly variation at -6.35% hinting at a possible recovery in the air freight market. However, this could also be due to a delayed busy holiday season which usually occurred in November in past years, but was observed a bit later in 2020 due to travel restrictions. This recovery could also be attributed to the approval of COVID-19 vaccines and the start of shipments.

Total revenue 2019 vs 2020

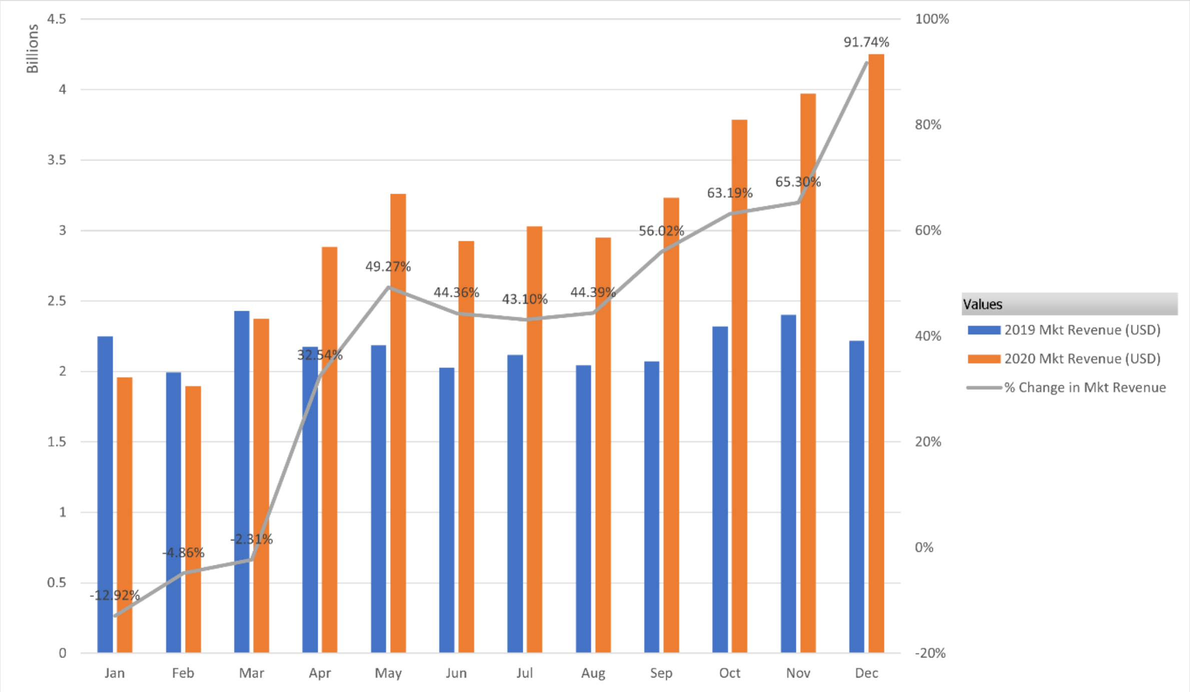


Fig. 32. *Total revenue 2019 vs 2020.*

Source: *CASS data, calculated by author*

2020 started with revenues below those of 2019 for the months of January, February, and March. However, despite the continuous decrease in volumes discussed above, the air freight industry witnessed record high revenues in 2020 after the start of the pandemic in April. The revenue increase ranged from 33% to 50% between April and August, then steadied at about 56 to 65% between September and November, to end the year with the highest increase at about double in December 2019, with a revenue increase of 92%.

Weight Charges per kg 2019 vs 2020

To understand this unique combination of decrease in volume transported and increase in revenues, we will look at the air freight charges per kg, a data point known as yield.

January and February started with a relatively average yield that was consistent with 2019 numbers. However, as the quarantine and travel regulations started taking place in various parts of the world, we see March showing the first increase in weight charge at 25%.

April saw the lowest number of flights and available CTKs and we see this reflected in the prices as the yield more than doubled in April and reached a historical high in May with near 120% increase. During the summer, as many travel restrictions lifted, we see the rates decreasing a little but nowhere near 2019 prices. The increase ranged from 78% and 87% between the months of June and October. The year ended with the freight prices increasing again and doubling again in November and December compared to the previous year.

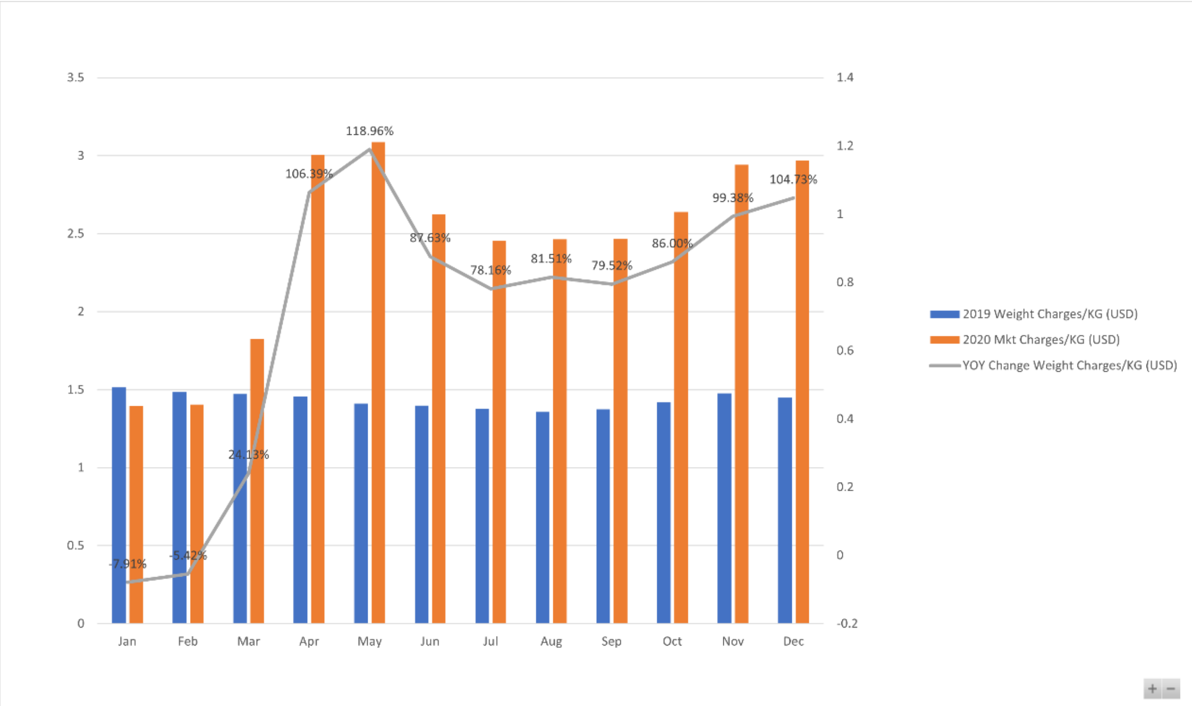


Fig. 33. *Weight charges per kg 2019 vs 2020.*

Source: *CASS data, calculated by author*

Top Origin Countries and Cities

Volume Changes in Top 10 Countries.

The previous graphs looking at the world averages show clear trends in both volumes transported and freight prices. However, the global trend is not always representative of the regional trends; therefore, we will have a look at the largest countries by origin of shipment. The graph below represents the top 10 origin countries and their corresponding exported air freight in both 2019 and 2020.

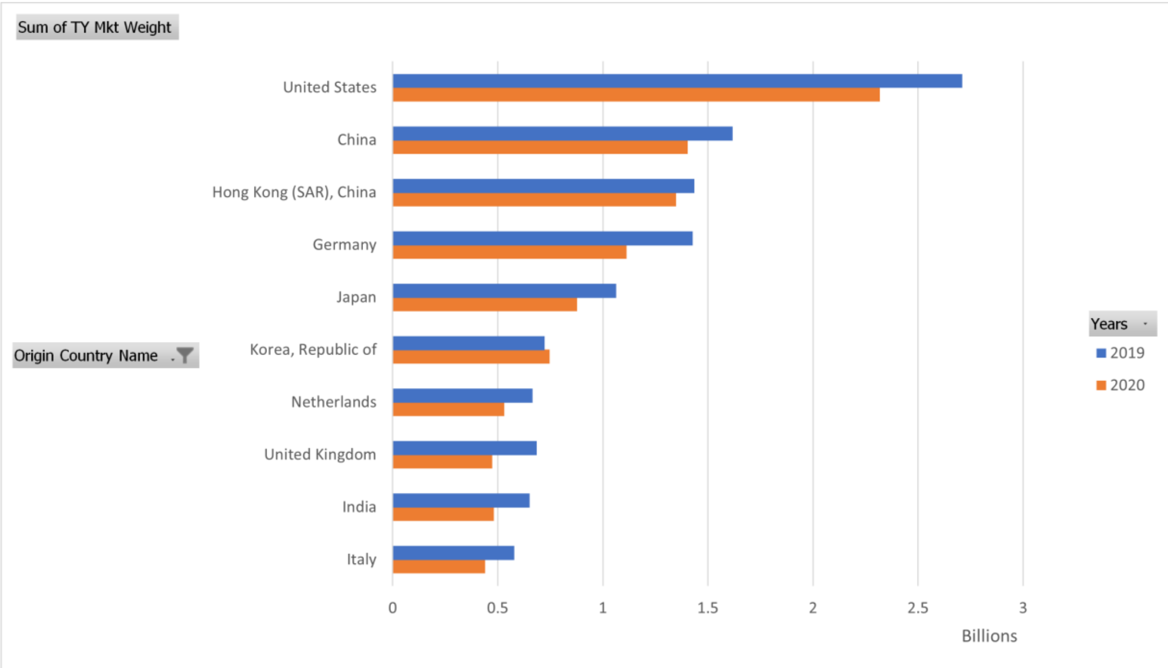


Fig. 34. *Volume change in top 10 countries 2019 vs 2020.*

Source: *CASS data, calculated by author*

All origin countries in the top 10 witnessed their transported volume decrease in 2020, except Korea which saw a 3.4% increase. We do notice that the decrease is lowest in Asian countries (except India) versus European and North American countries. Hong Kong and China and Japan had their annual volume decrease by 6%, 13% and 14.5% respectively where the rest had decreases ranging from 15% in the United States to 30% in the United Kingdom.

12 Months Volume Changes in Top 6 Countries

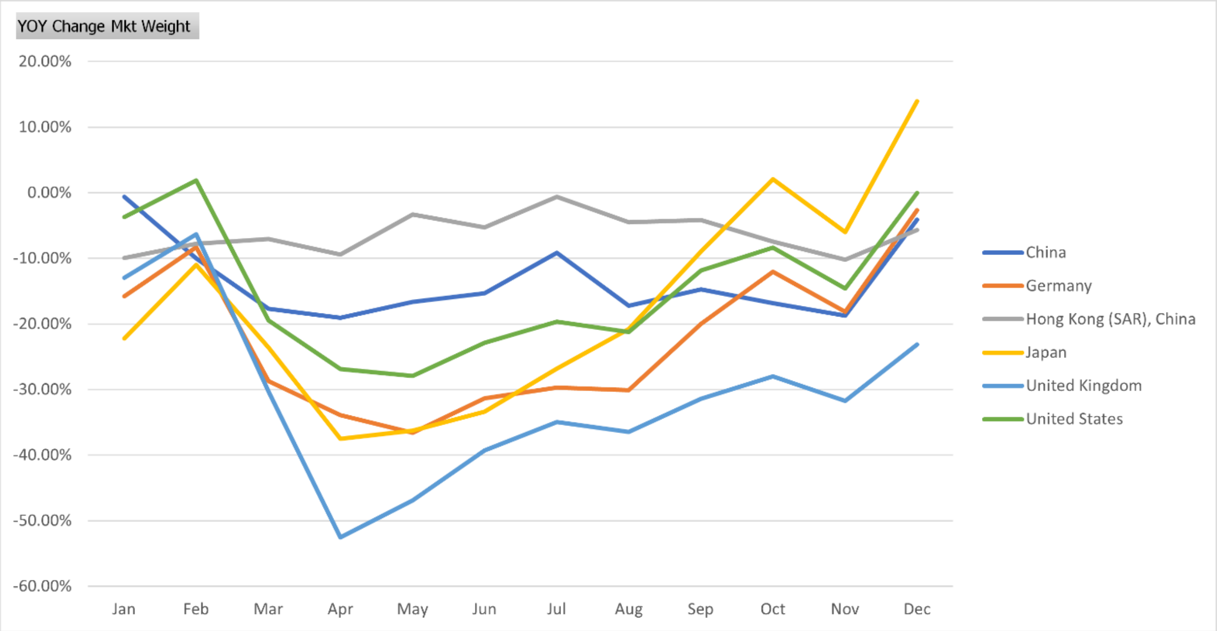


Fig. 35. *12 months volume change in top 6 countries 2019 vs 2020.*

Source: *CASS data, calculated by author*

A closer look at the top 3 countries in Asia (China, Hong Kong, and Japan) and the top 3 countries outside Asia (Germany, United Kingdom and United States), we see that China was affected early in February and continued to have its shipment volumes decrease compared to 2019 but slightly recovered afterwards with slight decrease between 10 and 20%. Hong Kong also seemed to have had the smallest variations in volumes compared to 2019. However, all non-Asian countries, in addition to Japan, were seeing historical lows ranging from -25% to over -50%, as was the case for the UK in the month of April. From July, we saw an overall slight recovery for all countries, but it did not go back to 2019 levels, except for Japan that returned to its numbers from the previous year in the month of October and continued growing afterwards.

In December 2020, Japan recorded a historical 13% increase versus December 2019 and all other countries except the United Kingdom had their best year-over-year performance in this month with the numbers almost matching those of 2019. The United Kingdom however had the worst performance and its numbers remained at -23% versus 2019. This was mainly due to the news of a new strain of the coronavirus being detected in the country. This news pushed many countries to close their air connection to the country, resulting in many cancelled flights.

Charges per kg YOY % Change in Top 15 Origin Countries

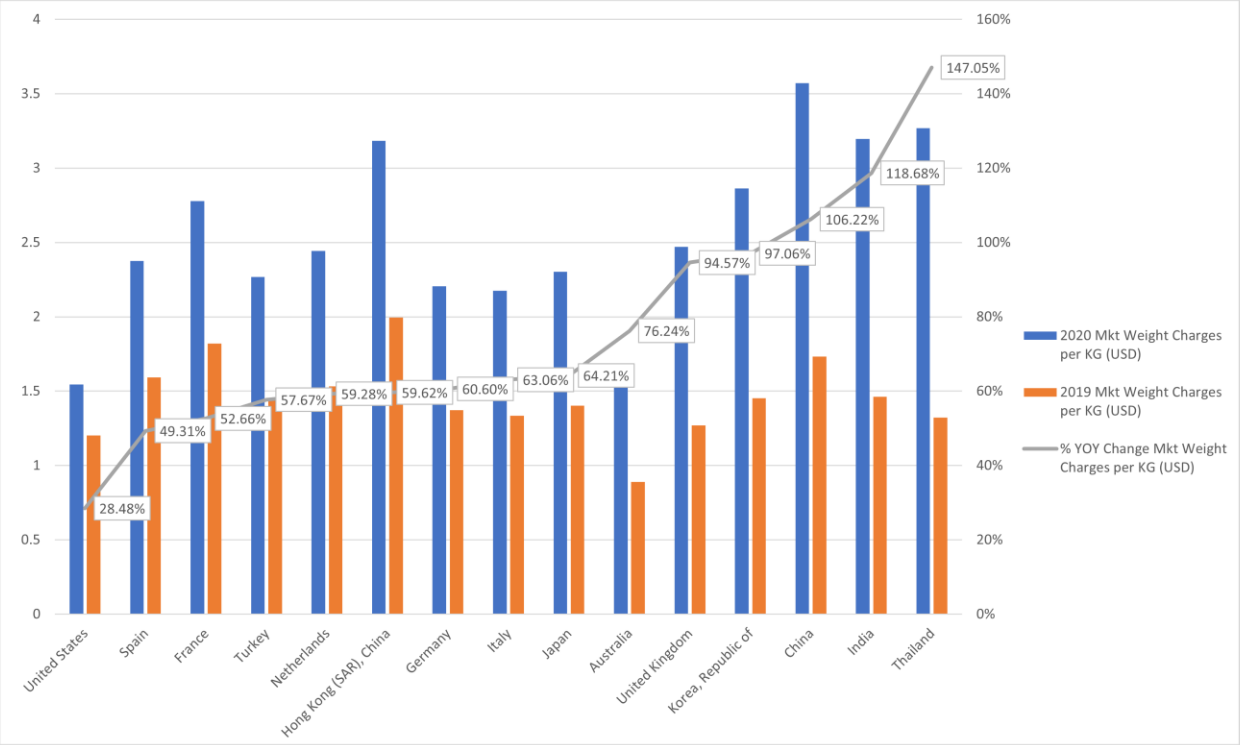


Fig. 36. *Change in charges per kg in top 15 origin countries, 2019 vs 2020.*

Source: *CASS data, calculated by author*

Looking at the changes in freight rates per kilogram in the top 15 origin countries, we notice that all of them saw increased prices, from a minimum of 28.5% for shipments originating in the United States to more than double for shipments originating from China, India and Thailand.

However, we do not notice a clear reason as to why some countries increased by more than others. We clearly see countries from various continents having both slight and large increases.

Volumes Changes in Top 10 Cities.

A look at the top 10 origin cities in 2019 and comparing their values to 2020, we see that there is a global decrease in volumes transported for every single city except Seoul, which shipped 6.4% more airfreight in 2020 compared to 2019.

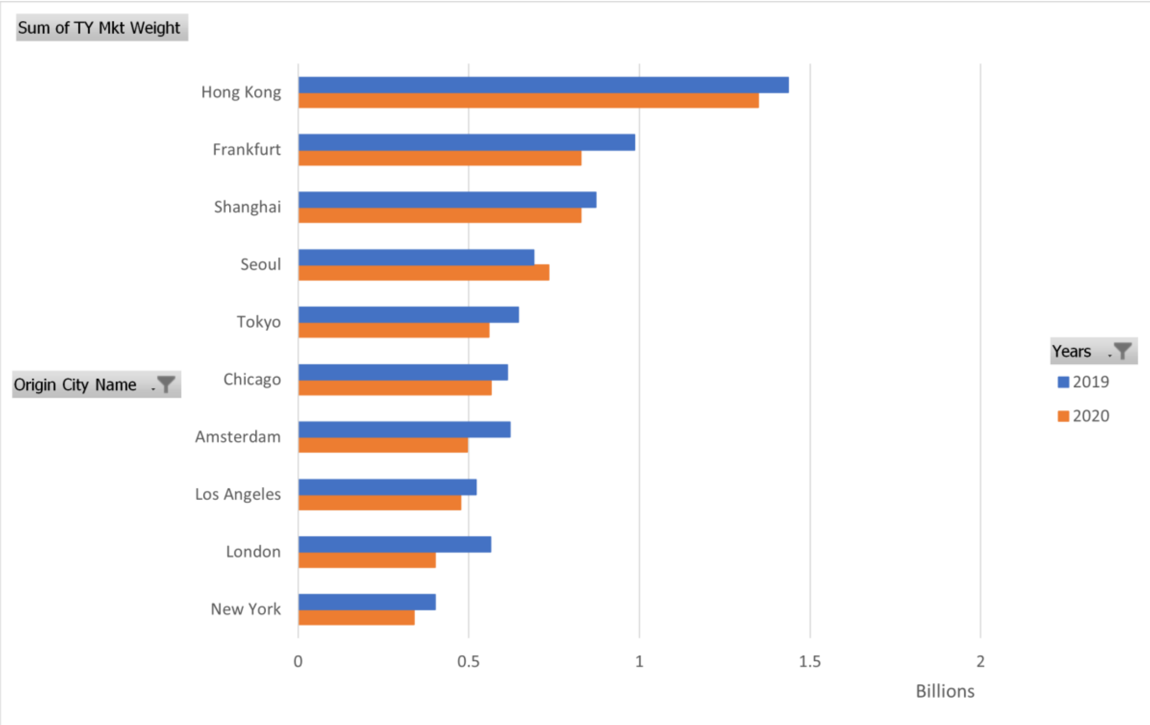


Fig. 37. *Volume change in top 15 origin cities 2019 vs 2020.*

Source: *CASS data, calculated by author*

This graph also shows Asian cities performing better than European and North American cities. Shanghai, Hong Kong, and Tokyo had their volumes decrease by 5%, 6% and 13% respectively. Whereas non-Asian cities had a larger decrease ranging from 8.6% for Los Angeles to 29% for London. This can also be explained by the fact that

Asian countries represent the largest producers of PPE equipment for which there was a large demand in 2020.

12 Months Volume Changes in Top 6 Cities

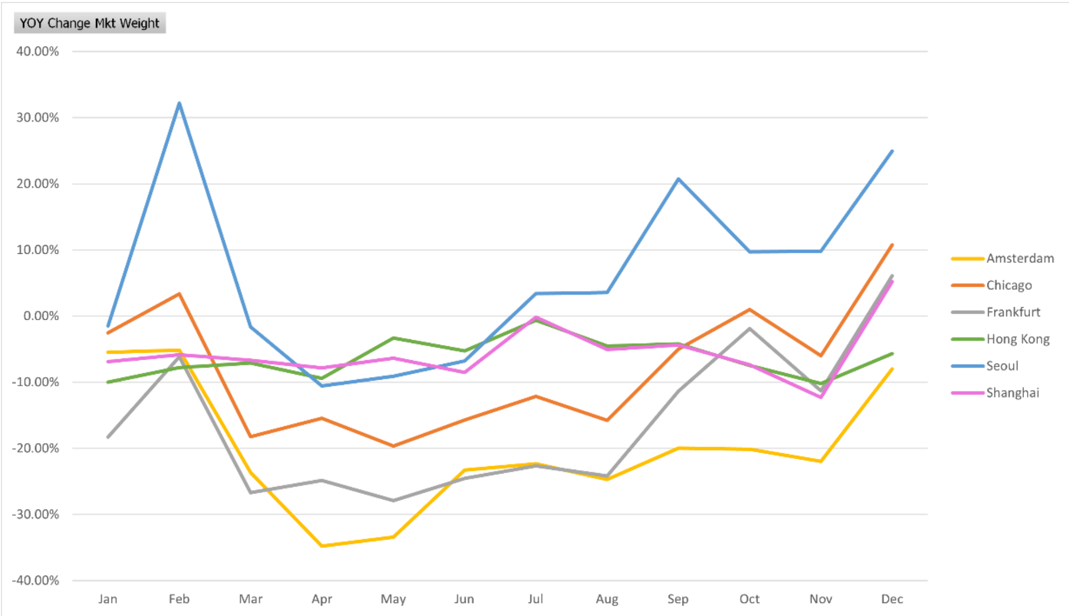


Fig. 38. *12 months volume change in top 6 cities 2019 vs 2020.*

Source: *CASS data, calculated by author*

This figure offers a further breakdown of monthly volume changes, focused on the top 3 cities in Asia (Hong Kong, Shanghai, and Seoul) and top 3 cities outside Asia (Amsterdam, Chicago, and Frankfurt). Seoul seems to have the strongest performance with its volumes dipping below 2019 levels only between March and June. We also notice a clear better performance for the Asian cities with their numbers going to only about -10% compared to 2019, whereas the non-Asian cities see their volumes dip considerably below 2019, reaching even below -30% at the worst of the year.

By the end of the year, most origin cities witnessed a slight recovery with their December 2020 numbers exceeding those of December 2019 except for Hong Kong and Amsterdam who only recovered to about -6.6% and -8% of their December 2019 performances.

Year over Year Percentage Change of Charges per kg in Top 15 Origin Cities

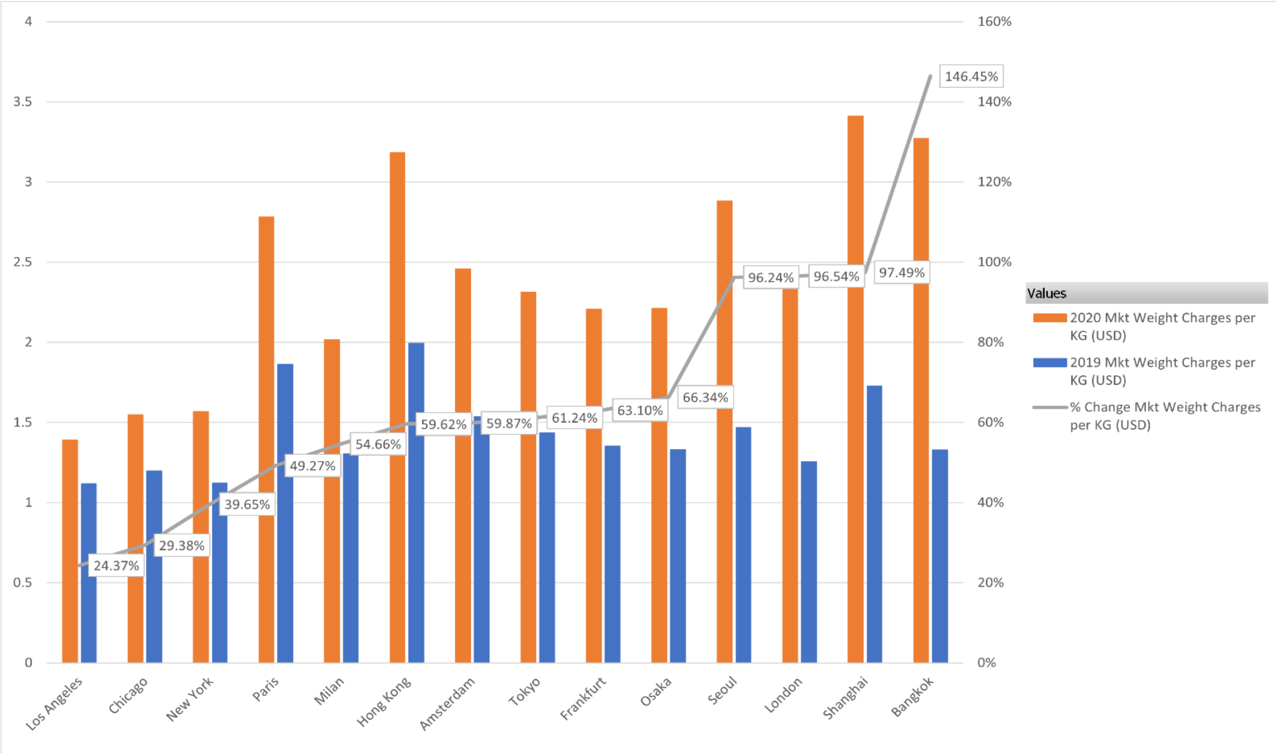


Fig. 39. *Change in weight charges per kg in top 15 origin cities 2019 vs 2020.*

Source: *CASS data, calculated by author*

Looking at the changes in freight charges per kg among the top 15 origin cities, we notice that all Asian origin cities had their volume increase by at least 55%, with the highest increases being recorded in Seoul and Shanghai.

The lowest yield increase was recorded in Los Angeles, Chicago, and New York, with increases ranging from 25% to 40%. We notice that the bottom 3 cities in terms of yield increase are all American cities. The United States had some of the loosest travel restrictions and therefore saw the least impact on available CTKs which could explain the lower increase in rates compared to other cities.

Analysis Breakdown by Region

Global Volume Broken Down by Region - 2019 vs 2020

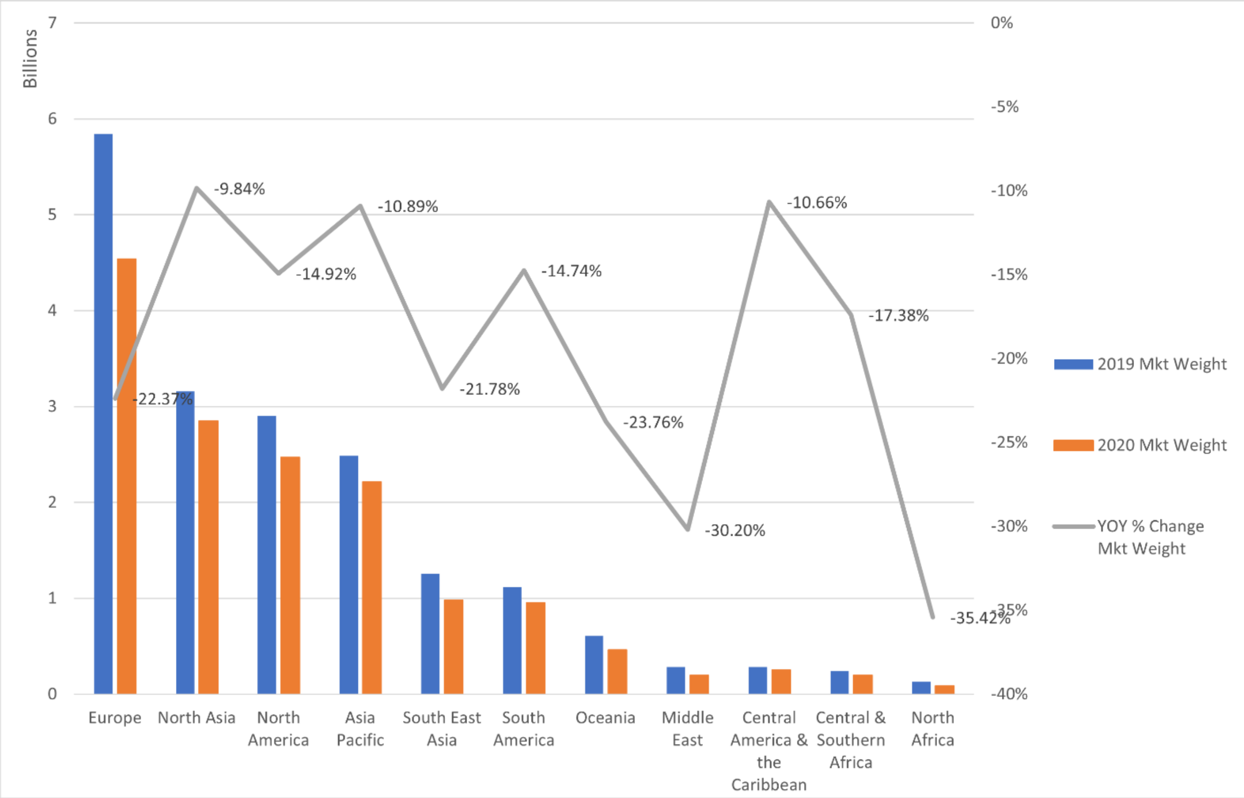


Fig. 40. *Volume change by region 2019 vs 2020.*

Source: *CASS data, calculated by author*

The regional analysis is based on the Official IATA regional breakdown. The list of all regions and their corresponding countries is listed in Appendix 3.

Looking at the global volume transported broken down by region, we noticed that the hardest-hit regions are North Africa and the Middle East at -35.5% and -30% respectively. The least impacted regions are North Asia, Asia-Pacific, Central America and the Caribbean at -9.84%, -10.89% and -10.66% respectively.

Year over Year Percentage Change of Charges per kg by Region

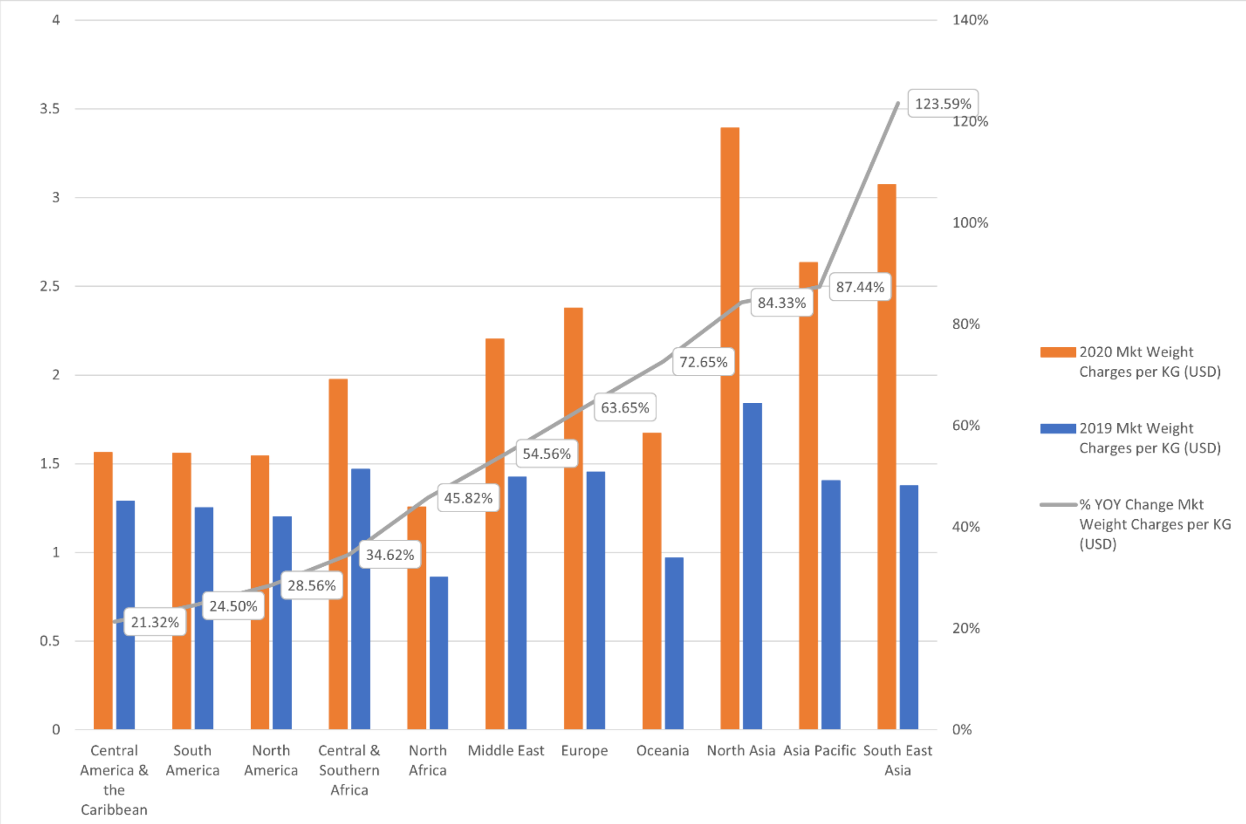


Fig. 41. *Change in weight charges per kg per region 2019 vs 2020.*

Source: *CASS data, calculated by author*

Looking at the yield changes by region, we notice the highest increases were all in Asia. The highest was an increase of about 123% recorded in South-East Asia, followed by Asia-Pacific at an 87% increase and 72% for North Asia. The least impacted in Central America and the Caribbean recorded a 21% increase and South America saw a 24.5% increase. The breakdown shows clearly that all regions were affected by the price increase in 2020, through the rates of increase differ from region to region.

Region to Region Volume Flow

Since trade partners vary for each origin point, we will further investigate region-to-region pairs. Below is the 2019 vs 2020 volume change for the top region-to-region trade lanes.

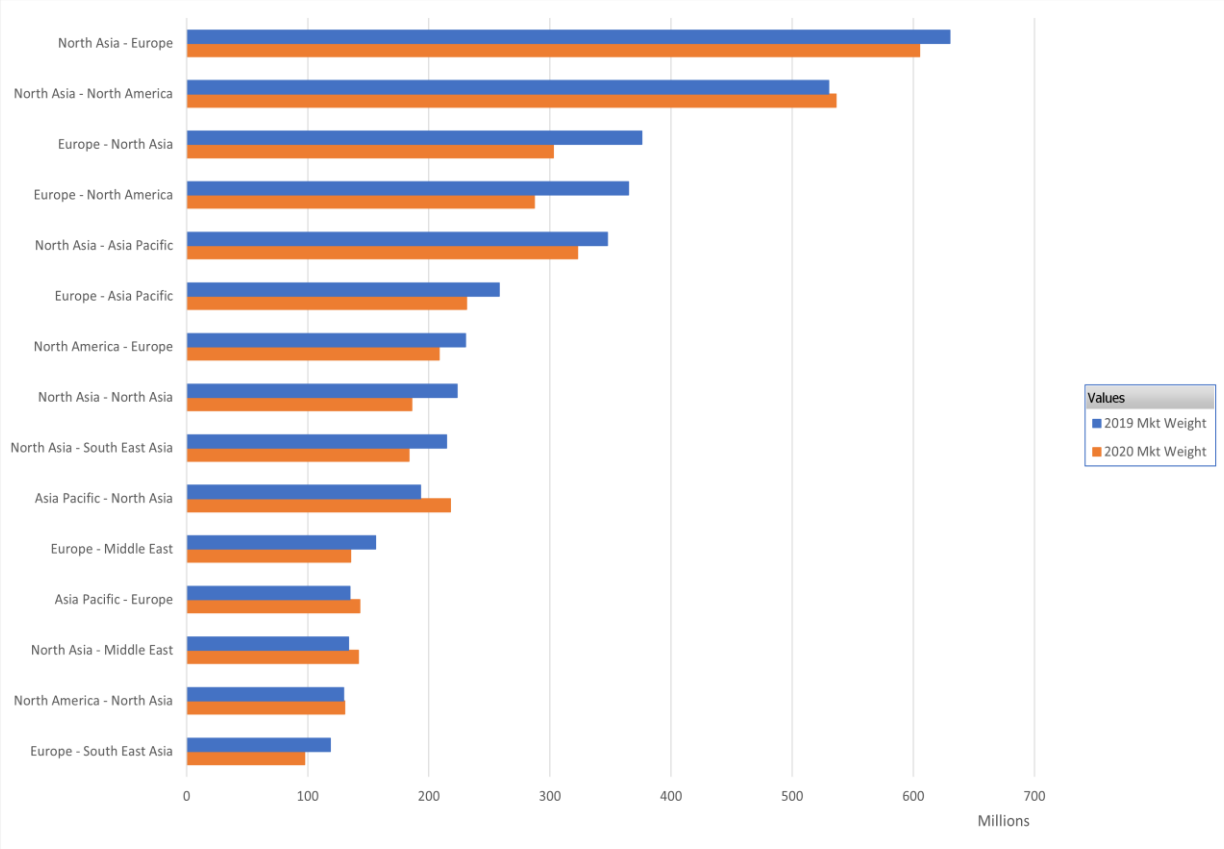


Fig. 42. *Weight transported with region-to-region breakdown 2019 vs 2020.*

Source: *CASS data, calculated by author*

The largest trade flow between regions as per IATA is North Asia to Europe, this trade lane recorded a 4% decrease compared to the previous year. For the same flow but in the opposite direction, Europe to North Asia recorded a 20% decrease. The second largest trade lane; North Asia to North America recorded a 1.15% increase. The highest growth is recorded at 12.9% for air freight transported from Asia-Pacific to North Asia.

Other pairs that recorded volume growth in 2020 in order of the largest growth to the smallest are: Asia-Pacific to Europe and North Asia to the Middle East at 6% growth each, and North America to North Asia at 0.6%.

The largest decreases are all for shipments out of Europe to North America, North Asia, and South-East Asia at -21%, -19.5% and -18% respectively.

Region Breakdown, % Change in Yield

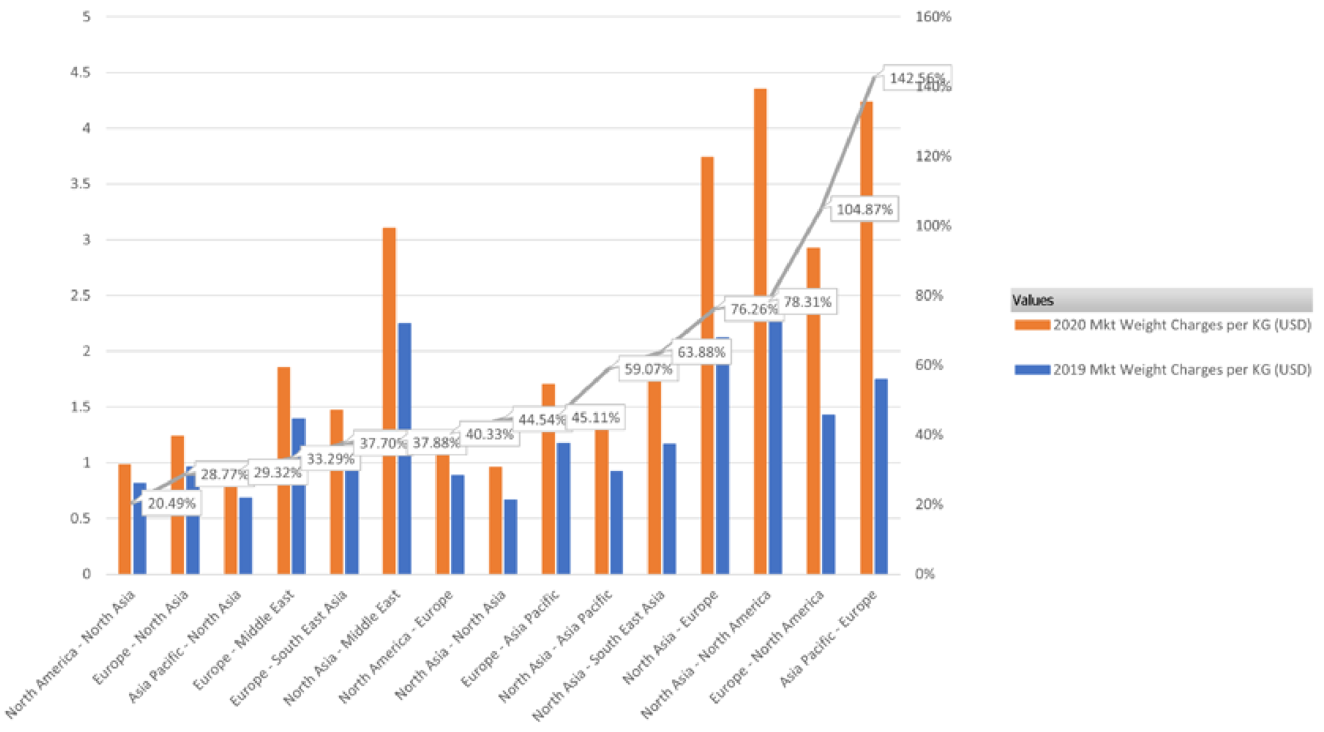


Fig. 43. *Change in weight per kg with region-to-region breakdown 2019 vs 2020.*

Source: *CASS data, calculated by author*

The highest increase in weight charges per kg are recorded for Asia to Pacific-Europe and Europe to North America at 143% and 104% respectively. The lowest increase is for the North America to North Asia and Europe to North Asia trade lanes.

City to City Volume Flow

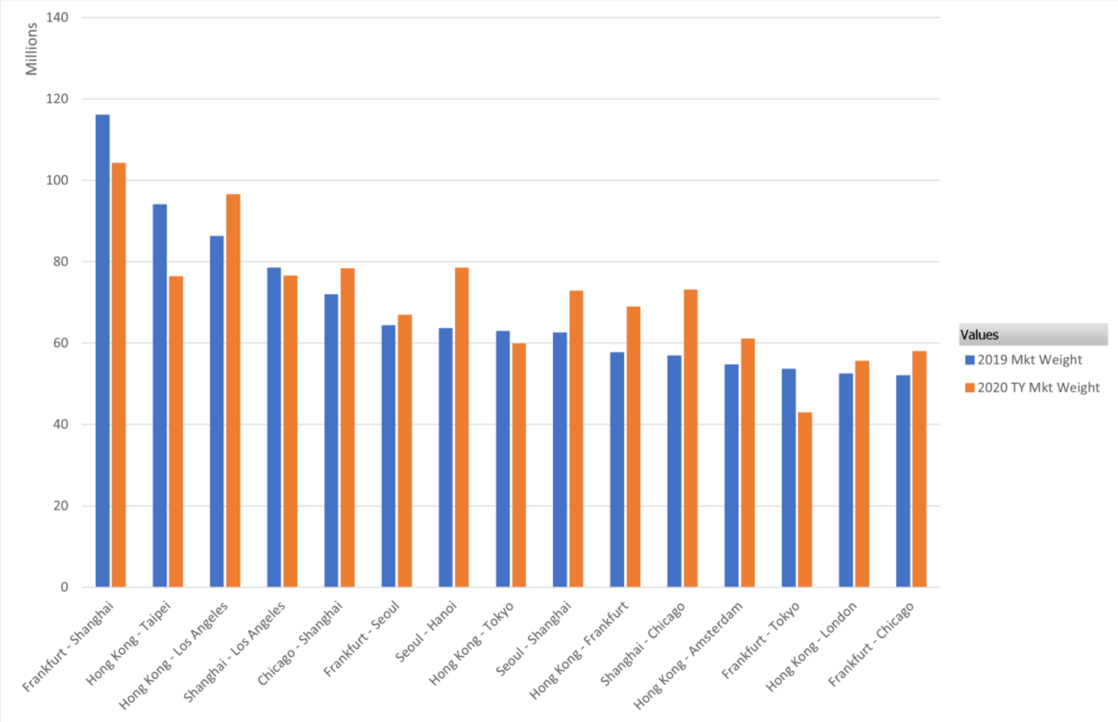


Fig. 44. *Weight transported with city-to-city breakdown 2019 vs 2020.*

Source: *CASS data, calculated by author*

Further analyzing the trade flow by the largest city to city trade flows, we see that all of them recorded volume growth except Shanghai-Los Angeles (-1.5%), Hong Kong-Tokyo (-4.8%), Frankfurt-Shanghai (-10.2%), Hong Kong-Taipei (-18.8%) and Frankfurt-Tokyo (-19.98%).

The highest growth was recorded from Shanghai to Chicago at 30%, followed by Seoul to Hanoi at 23% and Hong Kong to Frankfurt at 20%.

City to City Charges per kg

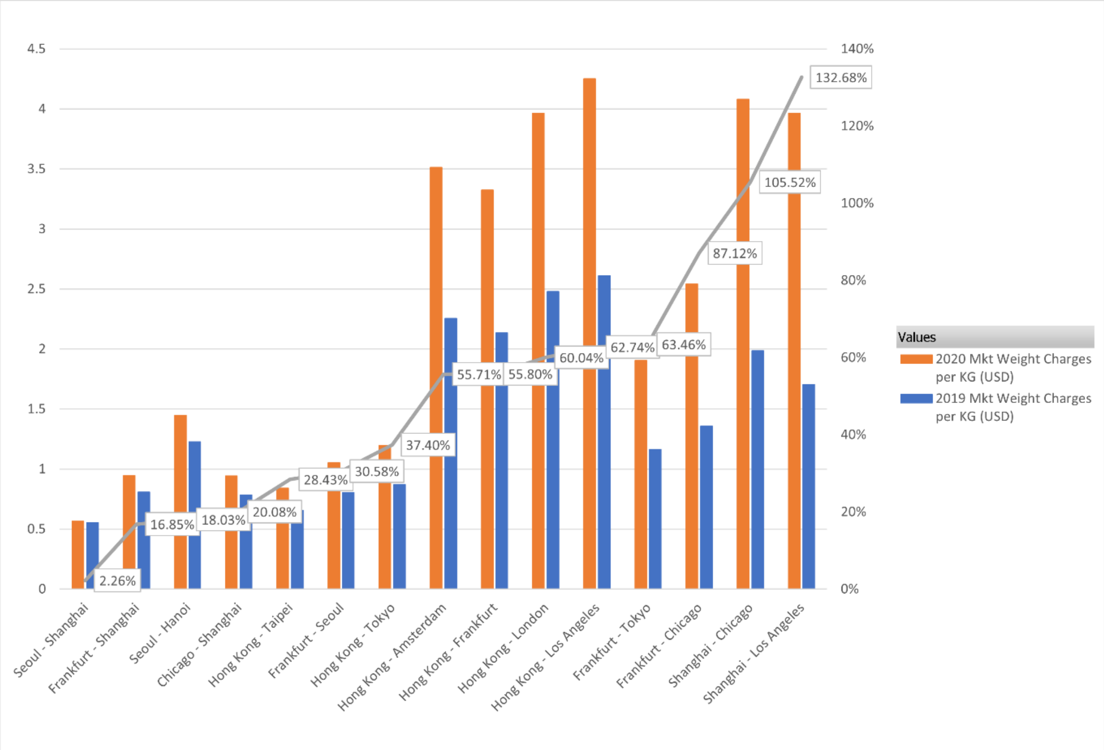


Fig. 45. *Change in weight charges pr kg with city-to-city breakdown 2019 vs 2020.*

Source: *CASS data, calculated by author*

When it comes to the rates on these trade lanes, shipments from Shanghai to both Chicago and Los Angeles had the highest increase with more than double the rates at 105% and 132% increase, respectively.

5.2. Capacity Data

Capacity data has proven much more difficult to obtain especially at the global level and with a similar level of breakdown as the data provided by CASS. Therefore, several sources of data had to be aggregated to provide a more comprehensive view of the evolution of freight capacity in 2020.

Even more challenging is the freight capacity breakdown by number of freighter flights compared to belly freight flights. We were not able to access such a breakdown, and we therefore decided to use the number of commercial flights as a proxy for the freight capacity available. Commercial flights include commercial passenger flights, cargo flights and charter flights. It does not include private flights, gliders, helicopter flights, ambulance flights, government flights and military flights.

For the global number of commercial flights, we used Flightradar24 statistics which provide the total number of commercial flights globally without a breakdown. And Euro Stat for the country and airport breakdown of the commercial flights out of all European countries. A breakdown by country and airports of commercial flights bound for other regions is not readily available, as many sources like US Gov and Canadian Statistics have not fully published 2020 data yet, and for other regions of the world, the data is not available publicly. Therefore, going forward with capacity data, we will focus on the global analysis and the regional analysis for Europe only.

5.2.1. Capacity Data Description – Flight Radar

Flightradar24 is a global flight tracking service. It combines live feed from several data sources including ADS-B (automatic dependent surveillance-broadcast), MILAT (Multilateration), satellite and radar data. It aggregates the data from over 20,000 network receivers worldwide. The website provides both real-time information about flights as well as statistical reports. For the capacity analysis, we will be looking at the total flights tracked by Flightradar24 in 2020 and compare this number to 2019. The report covers all commercial flights including commercial passenger flights, cargo flights and charter flights. This data is made public on the Flightradar24 website and is published with daily granularity. To remain consistent in our analysis, we aggregated the numbers monthly. There is no country nor airport breakdown for this data. A sample table is provided in Appendix4.

5.2.2. Capacity Data Description – Eurostat

Eurostat is the official statistical office of the European Union and it provides high quality statistics on the countries of the EU. Their reports cover the number of flights, and numbers of passengers, freight and mail transported. It is aggregated+ at the level of airport pairs, airports, and countries. The data is collected under European Parliament and Council Regulation 437/2003 by the European Organization for the Safety of Air Navigation (Eurocontrol). Additional information on infrastructure and fleet is collected on a voluntary basis through annual questionnaires. Data on freight transported would have been ideal for the purpose of our analysis, but the data is only available on an annual basis and therefore cannot be combined with the monthly pricing data provided by CASS. We instead decided to use the number of commercial flights in our analysis as a proxy for the capacity available for freight transport. The commercial flights data is available at country and airport levels with a monthly breakdown and covers the period from January 2019 to December 2020. A sample table is available in Appendix 5.

Even though Eurostat works under the overall structure of the European Union, the statistics available cover a total of 36 countries in Europe including the 27 in the European Union. The complete list of the countries included in the data set is available in Appendix 6.

5.2.3. Capacity Data Analysis

Global Analysis

The total number of commercial flights globally reached 41.9 million in 2019. This number went down to 24.4 million in 2020 representing a 42% decrease.

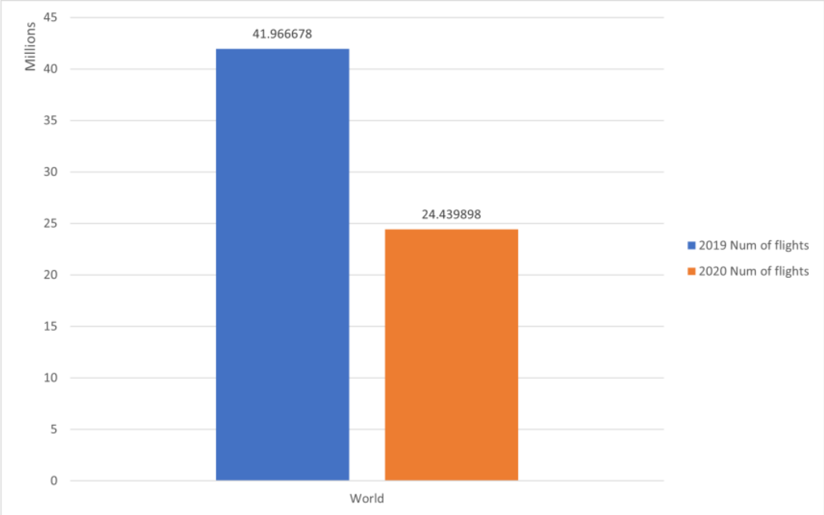


Fig. 46. *Total number of commercial flights 2019 vs 2020.*

Source: *Flightradar24 data, calculated by author*

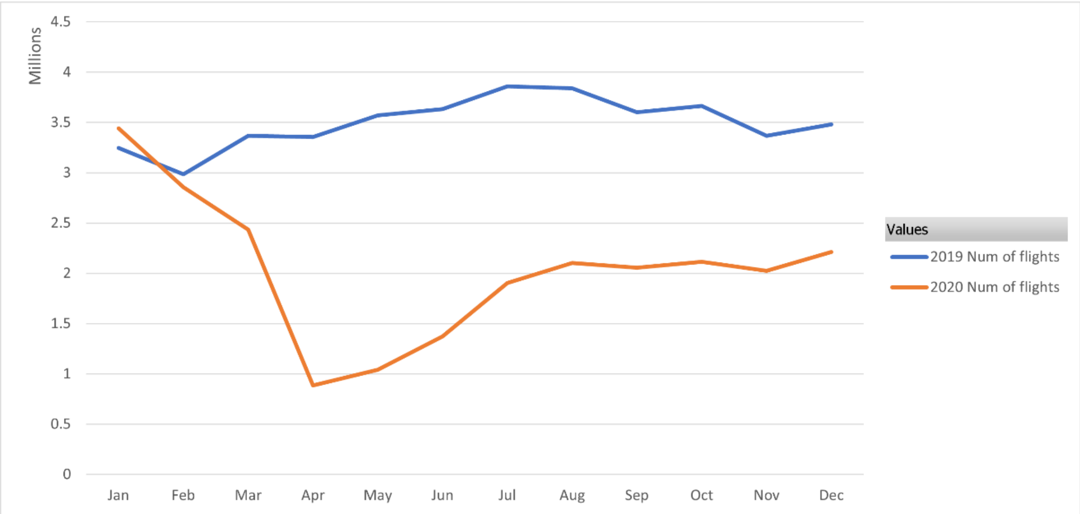


Fig. 47. *12 months breakdown of number of commercial flights 2019 vs 2020.*

Source: *Flightradar24 data, calculated by author*

The year started strong in January with flight numbers in 2020 surpassing those in 2019, but the numbers went down from there to reach the lowest dip in April. Following April, the global number of flights followed almost the same trajectory as the previous year with an increase in the summer and then a dip in the fall followed by a strong end of year. However, the difference year-over-year remained at about 1.5 million every month.

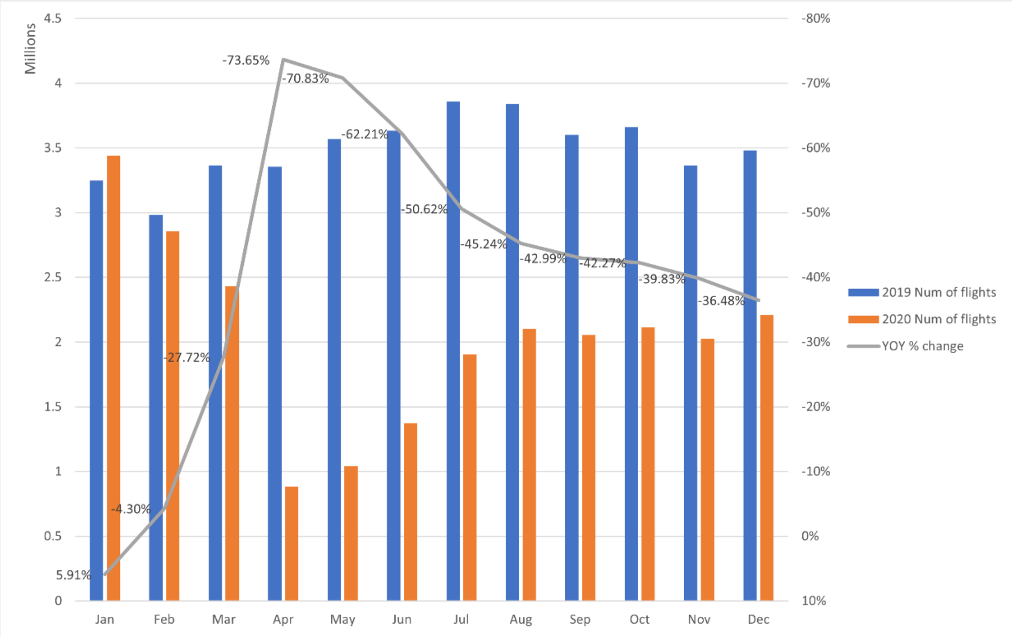


Fig. 48. *Change in number of commercial flights 2019 vs 2020.*

Source: *Flightradar24 data, calculated by author*

The largest variance of 2019 was in April with 73% decrease. The best month after April was December with only a 36% decrease.

Europe - Regional Analysis

We start this analysis by looking at the change in the number of flights for all 36 countries available in the data set and compare the 2020 numbers to the ones from 2019.

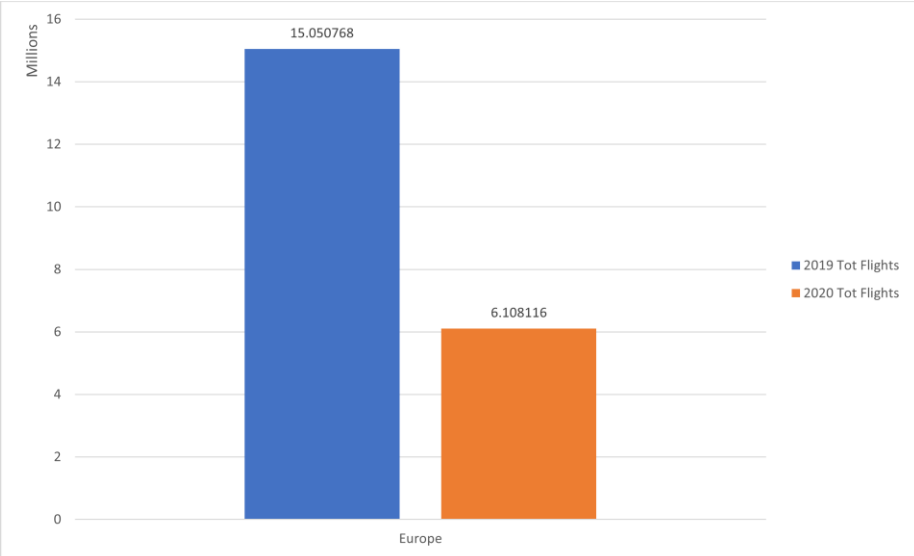


Fig. 49. *Total number of commercial flights in Europe 2019 vs 2020.*

Source: *Eurostat data, calculated by author*

The total number of commercial flights went down from 15 million to just over 6 million, reflecting a reduction of 59% in the total traffic in the region. We will now further investigate how did this variation evolve over the course of the year and if it affected countries differently.

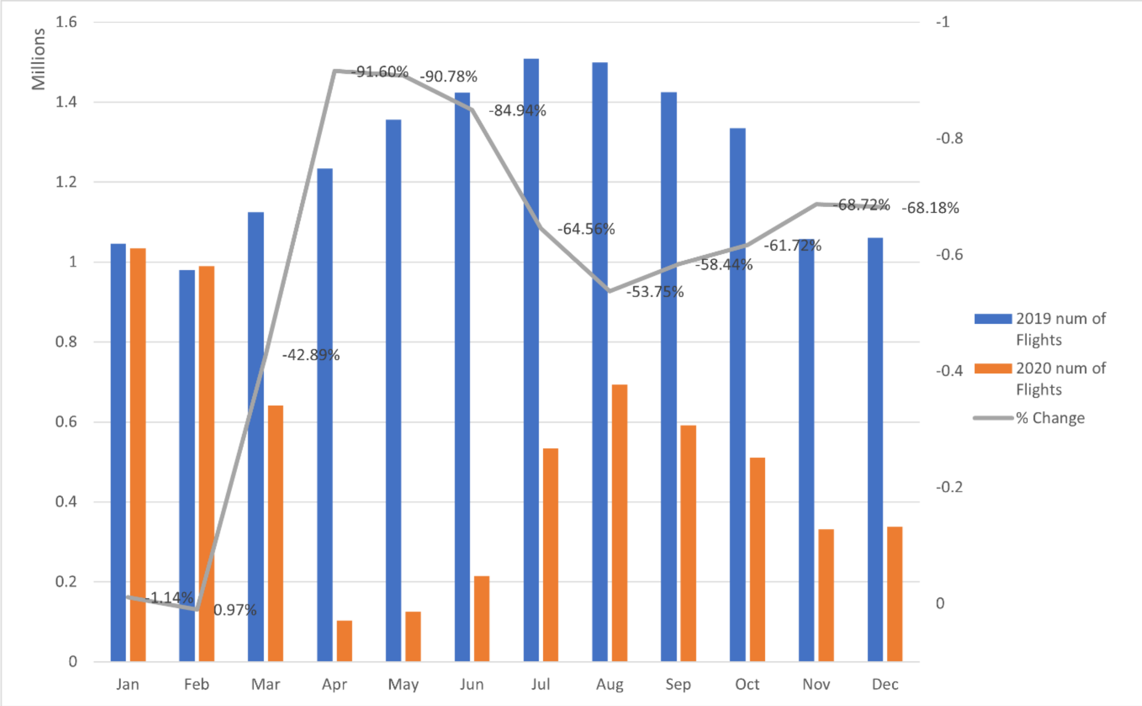


Fig. 50. *12 months breakdown of the number of commercial flights in Europe 2019 vs 2020.*

Source: *Eurostat data, calculated by author*

The 12-month breakdown for the European region shows the year starting at average rates with the number of flights recorded being just below the numbers for the same months from the previous year. March then saw a decrease in traffic by 42%, coinciding with the start of lockdown and travel restrictions in the region. April, May, and June recorded the lowest number of flights with the worst month being April with a 91.6% decrease in the number of flights.

Traffic seemed to slowly recover in July and August as travel restrictions were temporarily loosened before dipping again in September.

Europe - Country-Level Analysis

The top 5 countries by number of flights in Europe account for 54% of the total international flights for the continent. Germany and the UK each account for about 13%, followed by Spain at 11% and France and Italy at 9 and 8% respectively.

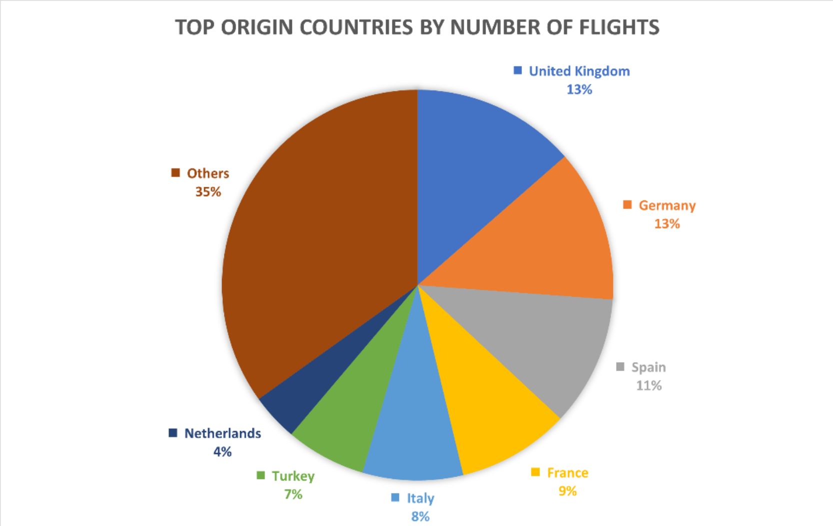


Fig. 51. *Top origin countries by number of flights in Europe 2019 vs 2020.*

Source: *Eurostat data, calculated by author*

Since Eurostat has data for over 27 countries, we will focus on the largest countries by number of flights and continue the analysis for the top 10 by number of flights. The next graph shows the 2020 number of flights compared to 2019 number of flights and the year-over-year percentage change, reflected by the grey line.

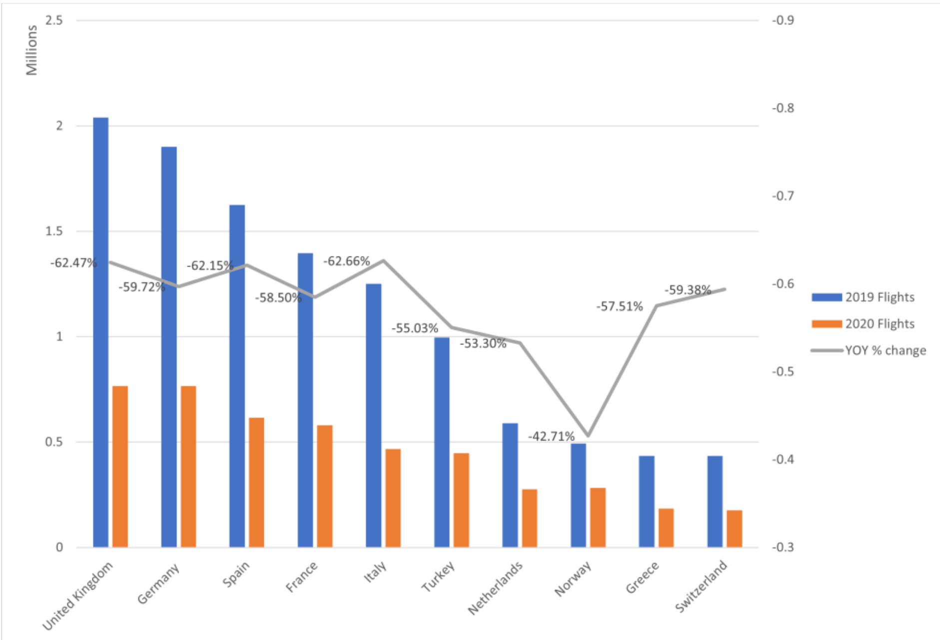


Fig. 52. *Change in number of flights for top 10 countries in Europe 2019 vs 2020.*

Source: *Eurostat data, calculated by author*

All of the top 10 countries by number of flights in 2019 saw their traffic decline from 53 to 62% except Norway that was less affected and only lost about 42% of its traffic.

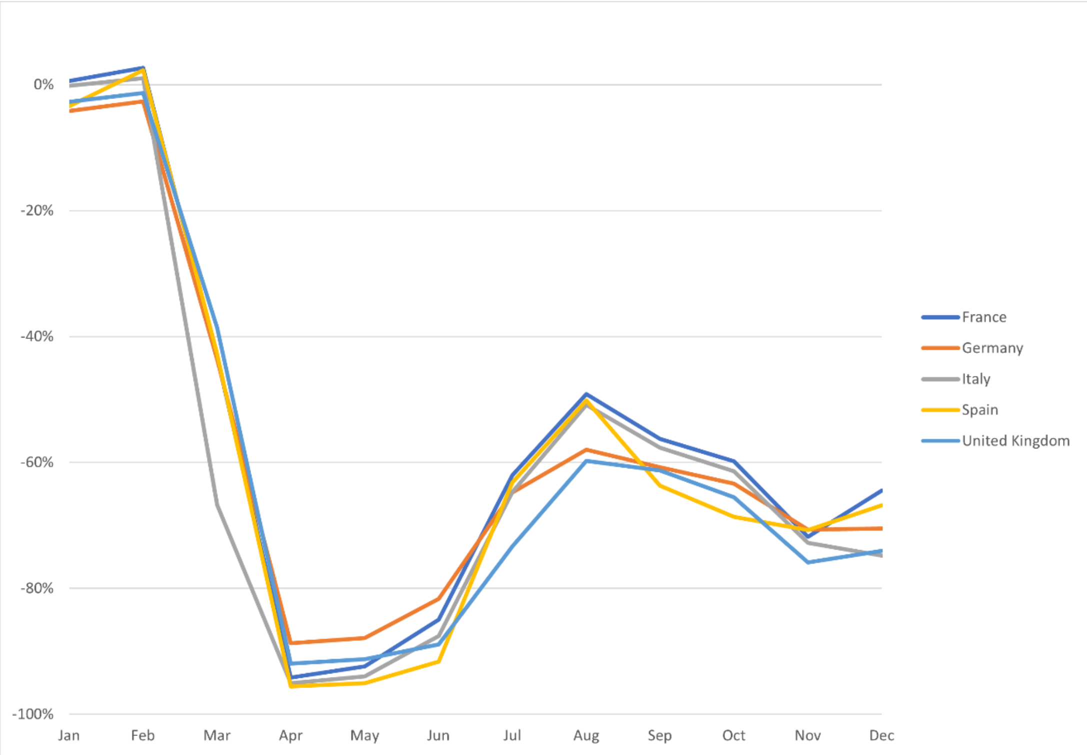


Fig. 53. *12 months change in number of flights for top 5 countries in Europe 2019 vs 2020.*

Source: *Eurostat data, calculated by author*

The top 5 European countries were all equally affected in 2020, they even follow the same progress path with the highest declines recorded in the month of April and reaching 96% for Spain and 95% in Italy. This decline stayed sharp in May and then recovered slowly from June to August. The second wave in September caused the number of flights to decrease again until the end of November followed by signs of recovery in December.

Europe - City-Level Analysis

The data from Eurostat is available at the airport level. To be consistent with CASS data previously analyzed, airports were grouped by the city they operate in. For example, Paris would include the data for both Paris-Charles de Gaulle Airport (CDG) and Paris Orly Airport (ORY). A table for city-airport combinations is provided in Appendix 7.

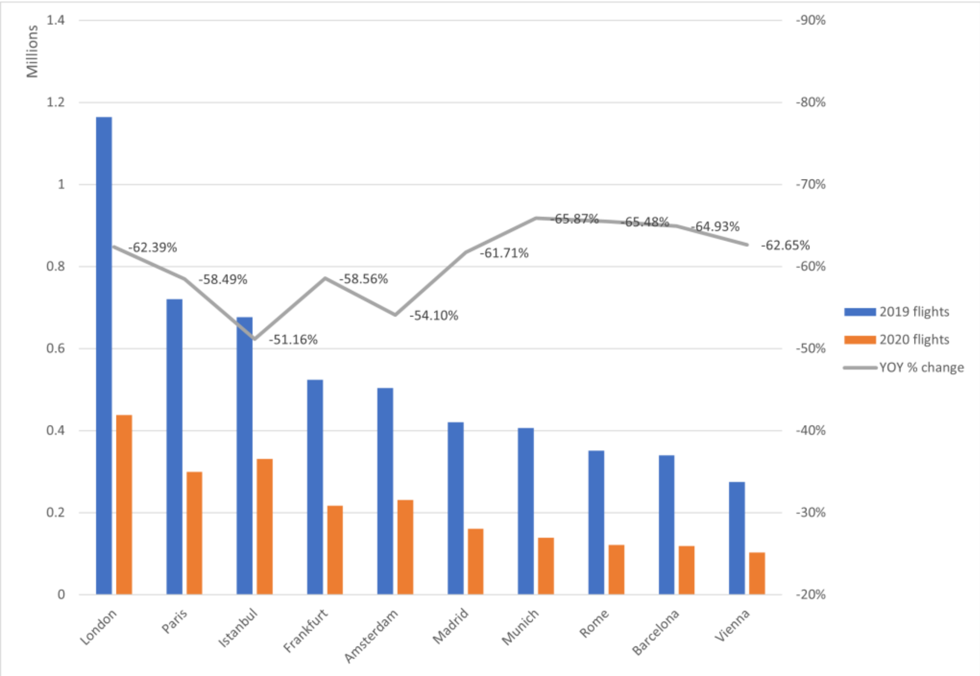


Fig. 54. *Number of flights in the top 10 cities in Europe 2019 vs 2020.*

Source: *Eurostat data, calculated by author*

All top 10 airports saw their volumes decrease in 2020 from 51% to 75%, with Rome, Barcelona, Vienna, and London being some of the most affected. On the other hand, Istanbul, Amsterdam, Paris, Frankfurt, and Munich were the least affected.

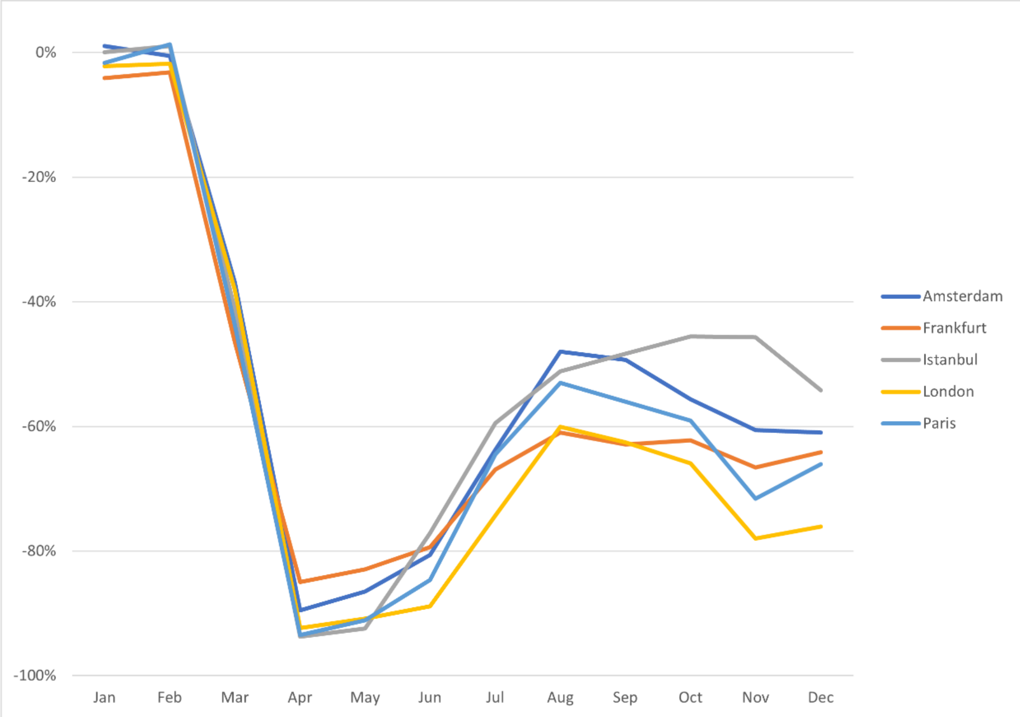


Fig. 55. *Change in number of flights in the 5 busiest cities in Europe 2019 vs 2020.*

Source: *Eurostat data, calculated by author*

The evolution of capacity over 12 months for the 5 busiest cities shows a similar start with a sharp decline in April and May then a slow recovery between June and August. Istanbul and Amsterdam had a better performance towards the end of the year. Frankfurt and Paris saw a medium recovery and London had the weakest year-over-year numbers.

5.3. Air Connectivity Index Data

Several measures exist for air connectivity indexes as discussed in the literature review section. For the data analysis, we used both Air Connectivity Index measures from the IATA and the Airports Council International Europe. IATA's measure was used for the global analysis at the country level, while the connectivity measure from the Airports Council International Europe was used for the analysis on flight capacity from European airports, as this is the only source that measures the air connectivity at that level. This data keeps track of three metrics: direct connectivity, indirect connectivity, and airport connectivity, which reflects the first two. We used the latest for our calculations.

For both sources, ACI measures are only available on an annual basis. A sample table is provided in Appendix8 for the IATA's ACI and Appendix 9 for the Airports Council International Europe ACI.

5.4. Travel Restrictions Data

Travel restrictions data was collected from the University of Oxford COVID-19 Government Response Tracker known as OxCGRT. This tracker database gathers information on the different government policies put in place as a response to the pandemic and covers over 180 countries. The travel restrictions measure gives a rating from 0 to 4 based on the extent of the policies (Oxford University, 2021).

0-No measures

1-Screening

2- Quarantine arrivals from high-risk regions

3-Ban on high-risk regions

4- Total border closure

The data is available daily and for the purpose of our analysis was aggregated at the monthly level using an average, min, and max calculations. A sample of the data is provided in Appendix10.

5.5. Relations between Key Variables of Interest

When looking at the connection between the change in air cargo pricing, the air connectivity index, the number of COVID cases and travel restrictions, we will run the numbers based on the global data set for pricing (72 countries available in CASS data). However, when analyzing for capacity changes, the analysis will be limited to the 28 European countries and the 47 airports available in the Eurostat data set.

To have an initial view of the trend, we plotted the relationship between the annual change in weight charges per kg and the annual ACI value for 2019 for all countries in the database. The graph shows a positive correlation meaning that the countries with higher ACI values witnessed a higher increase in the weight charges per kg.

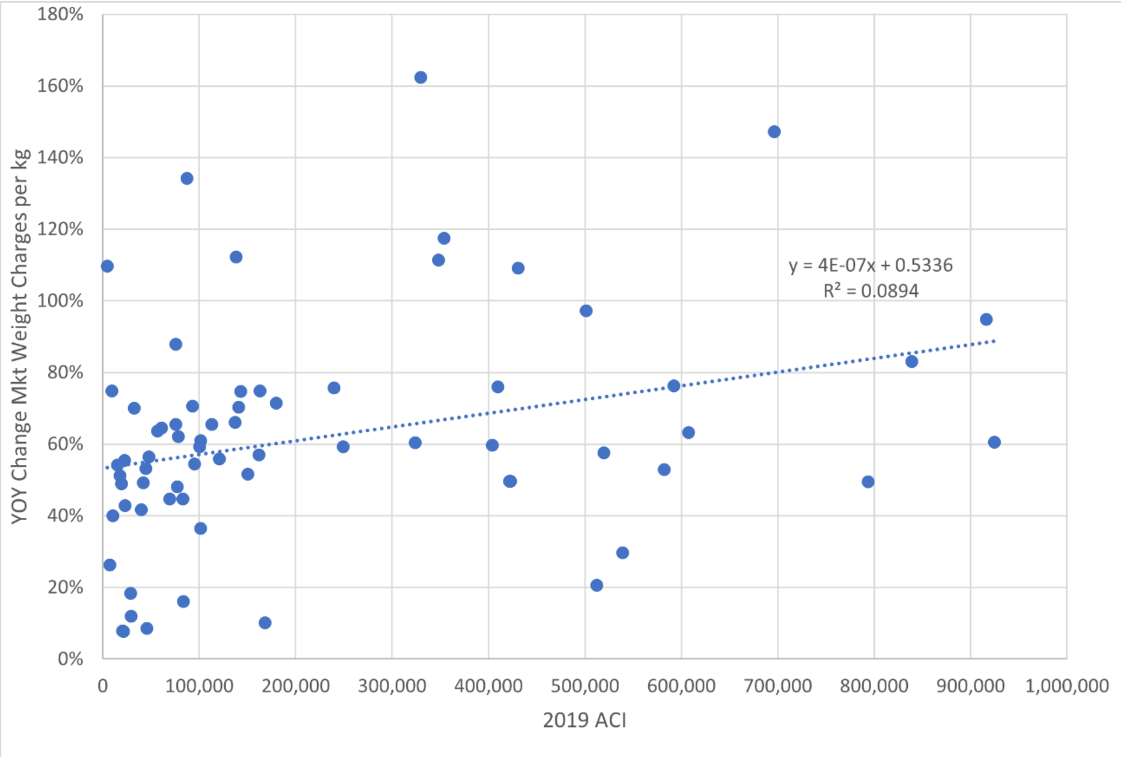


Fig. 56. *Linear regression of ACI and change in weight charges pr kg for all countries*

Source: *calculated by author*

We plotted the same graph for European airports and the positive correlation remains.

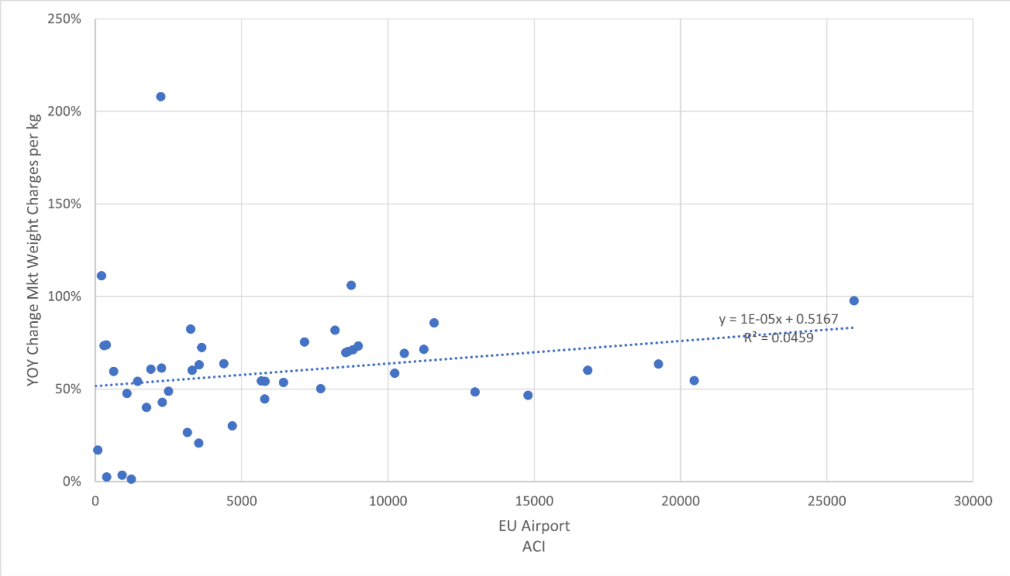


Fig. 57. *Linear regression of ACI and change in weight charges pr kg for EU airports*

Source: *calculated by author*

The change in the number of flights from European airports in correlation with the freight price shows a negative relation, as a decrease in capacity correlates with an increase in freight prices per kg.

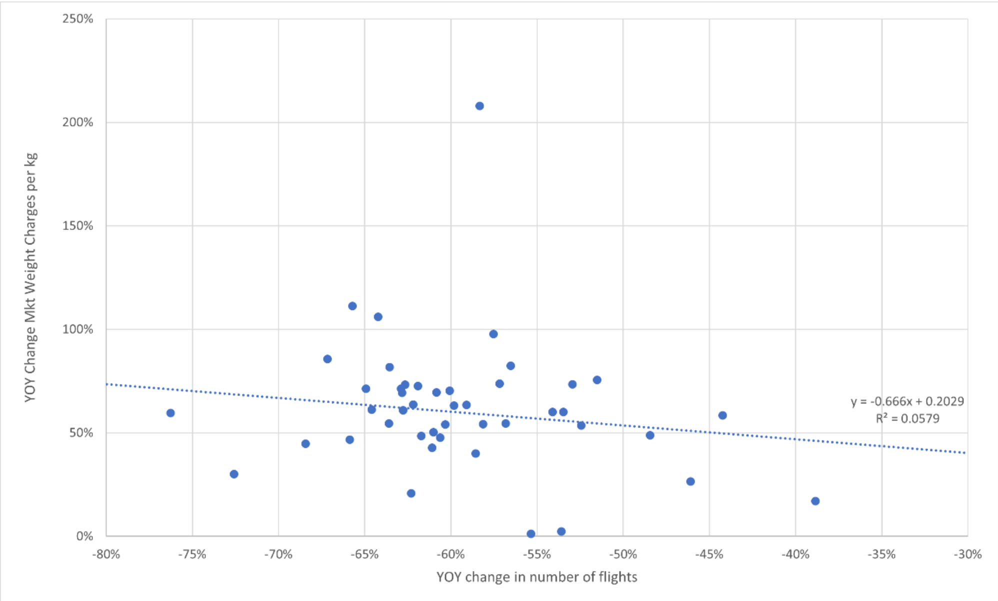


Fig. 58. *Linear regression of change in number of flights and change in weight charges pr kg for EU airports*

Source: *calculated by author*

The same observation holds at the country level with an even higher R square value.

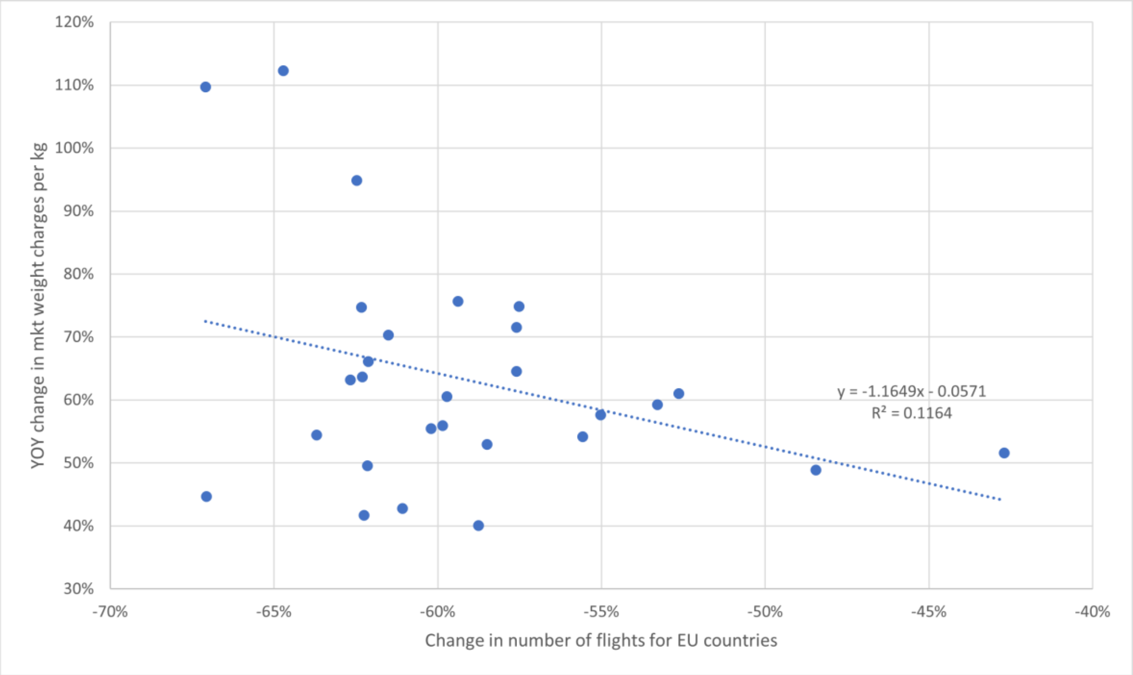


Fig. 59. *Linear regression of change in number of flights and change in weight charges pr kg for EU countries.*

Source: *Calculated by author*

We then plotted the changes in weight charges per kg for all countries in the database as a function of the number of COVID cases per million. We notice a downward trend meaning that a higher number of COVID cases did not necessarily mean a greater increase of freight prices.

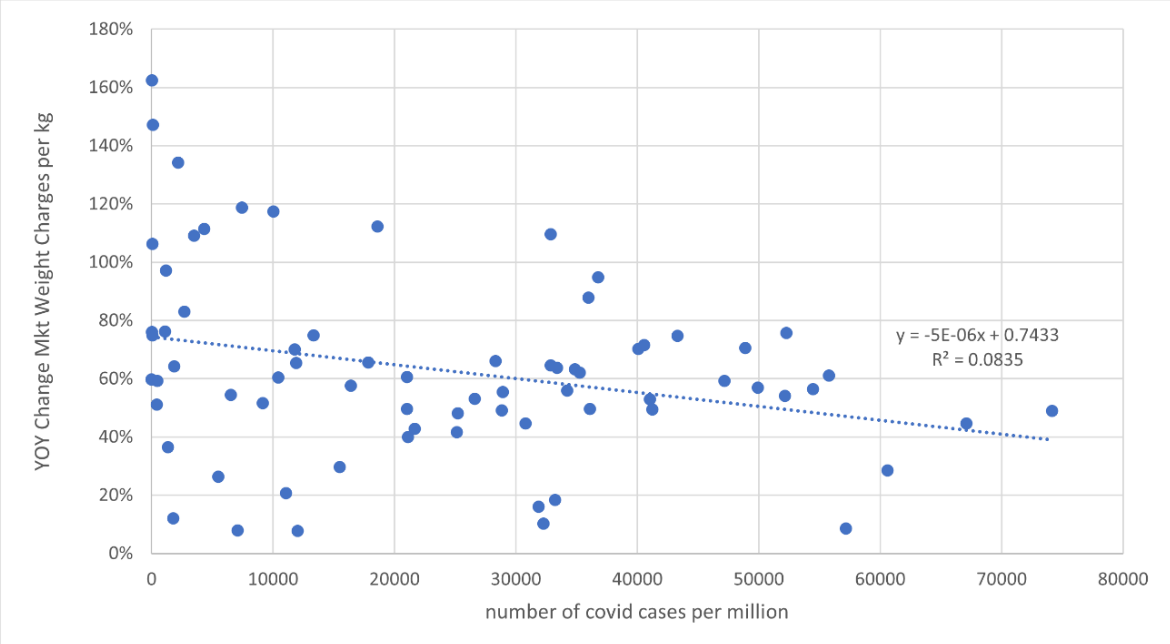


Fig. 60. *Linear regression of the number of COVID-19 cases per million and change in weight charges pr kg for all countries.*

Source: *calculated by author*

5.6. Regression Results

We will start the regression analysis by evaluating the relation between air freight price growth in 2020 and the independent variables, namely ACI, prevalence of COVID cases and travel restrictions at the global level. Capacity growth is omitted since it is only available for Europe and will be analyzed later on.

Regression Results for All Countries

Below is the summary table for the descriptive statistics of our dependent and independent variables for all countries in the database. When evaluating the correlation between the various variables in the model (which we do not report), we notice that the weight transported is correlated with the ACI with a coefficient of 0.84 and a p-value of 0.00, indicating a significant correlation. The same is valid for the number of COVID cases and the travel restrictions, with a coefficient of 0.123 and a p-value of 0.0002, which is higher than the significance level of 0.05.

Summary of statistics for benchmark for all Countries

Variable	*Mean*	*Std. Dev.*	*Min*	*Max*
Y (Yield growth)	0.68	0.58	-0.32	2.87
MktW (Market Weight)	20,900,000	37,300,000	118,953	259,000,000
COVID (number of COVID cases)	1,965.86	3,851.49	0.00	29,623.58
ACI (Air Connectivity Index)	440,257.00	1,135,598.00	4666.00	8,130,508.00
TR (Travel restriction)	2.54	1.26	0.00	4.00

Table 8. Summary of statistics benchmark for all countries

Source: Author's calculations

The empirical results from the regression are provided in Table 9. The R square of this equation is 0.212. The results in the first column suggest that the prevalence of COVID-19 in a country is positively related to air freight prices, confirming that countries that were harder hit by the pandemic saw a larger increase in air cargo rates. Similarly, we found a positive relation between the degree of travel restrictions that a country imposed and the growth rate in air freight prices in 2020. The weight transported in 2019 (indicator of the market size) and the Air Connectivity Index have P-value of 0.83 and 0.74 respectively, indicating that there is not sufficient evidence to conclude to a non-zero correlation.

Table 9
Results of the regression analysis

Dependent variable: change in air freight prices in location i for month t	*All countries*	*EU Countries*	*EU airports*
MktW (Market Weight)	-1.42E-10	-9.65E-10	-7.19E-09***
	[6.87e-10]	[8.69e-10]	[2.19e-09]
Cap (Capacity growth)	-	-1.29428***	-0.025429**
		[0.9354]	[0.0105684]
COVID (num of COVID cases)	0.000015***	0.0000173***	0.0000191**
	[3.82e-06]	[3.69e-06]	[7.63e-06]
ACI (Air Connectivity Index)	9.26E-09	9.56E-08	0.0000204***
	[2.80e-08]	[1.06e-07]	[5.94e-06]
TR (Travel Restrictions)	0.2032916***	-0.290249	0.1902814***
	[0.0116847]	[0.229462]	[0.0182931]
Observations	863	335	538
R-square	0.2128	0.6278	0.054

Table 9. Results of the regression analysis

Source: Author's calculations

We also estimated standardized beta coefficients in Table 10 to identify which factors had a larger influence on the growth in air freight prices. The results in column 1 confirm that the travel restrictions contributed the most to the variations seen in price changes, followed by the prevalence of COVID-19 in a country. Market size has the lowest contribution after the Air Connectivity Index, which can be seen in its low significance level.

Table 10 *Results of the regression - Standardized Beta*			
Dependent variable: change in air freight prices in location i for month t			
	All countries	*EU Countries*	*EU airports*
MktW (Market Weight)	-0.0091017	-0.05059387	-0.0888789
Cap (Capacity growth)	-	-0.7892994	-0.0558191
COVID (num of COVID cases)	0.0989838	0.1768977	0.0759424
ACI (Air Connectivity Index)	0.0179583	0.0524776	0.0959784
TR (Travel Restrictions)	0.4386038	-0.070484	0.1798658

Table 10. Results of the regression analysis, standardized beta

Source: Author's calculations

Regression Results for EU Countries

When looking at EU countries, we were able to add capacity growth on top of the previously used variables, such as the number of COVID cases, ACI, weight transported and travel restrictions.

Below is the summary table for the descriptive statistics of our dependent and independent variables for all the European countries in the database. When evaluating the correlation between the various variables in the model (not reported), we conclude to a highly significant correlation between weight transported and ACI, number of COVID cases and travel restrictions. Capacity growth is connected to both travel restrictions and number of COVID cases.

Summary of statistics for benchmark for EU countries

Variable	*Mean*	*Std. Dev.*	*Min*	*Max*
Y (Yield growth)	0.70	0.50	-0.32	2.24
Cap (Capacity growth)	-0.57	0.31	-0.97	0.18
MktW (Market Weight)	134,000,000	26,300,000	120,586	134,000,000
COVID (number of COVID cases)	2895.84	5138.73	0.00	29,623.58
ACI (Air Connectivity Index)	233,667.80	275,113.60	4666.00	924,731.00
TR (Travel restriction)	2.34	1.22	0.00	4.00

Table 11. Summary of statistics benchmark for EU countries

Source: Author's calculations

As shown in the second column of Table 9, the R square of this equation is much higher than in the analysis at the global level with a value at 0.6278. Similar to the results from the analysis for all countries (column 1 of Table 9), these regression results confirm that the growth of air freight prices was higher in those European countries that had a greater prevalence of COVID-19 cases. However, the relation between travel restrictions and air freight prices no longer seems significant. Most interestingly, these results confirm that capacity growth is negatively correlated with air freight prices.

The standard beta in column 2 of Table 10 allows us to identify the highest contributors to the change in air freight charges, namely the capacity growth and the prevalence of COVID cases.

Regression Results for EU Airports

The next part of the regression involved the same variables as for the European countries except that we analyzed it with more granularity, at the airport level.

Below is the summary table for the descriptive statistics of our dependent and independent variables for the European airports in our database. When evaluating the correlation between the various variables in the model (not reported), we conclude that the ACI is highly correlated with airport size. Travel restrictions are highly correlated with both capacity growth and number of COVID cases.

Summary of statistics for benchmark for EU airports

Variable	*Mean*	*Std. Dev.*	*Min*	*Max*
Y (Yield growth)	0.73	1.24	-0.45	25.52
Cap (Capacity growth)	-0.35	2.73	-1.00	46.61
MktW (Market Weight)	8,451,706	15,400,000	12	94,400,000
COVID (number of COVID cases)	2895.84	5138.73	0.00	29,623.58
ACI (Air Connectivity Index)	6449.41	5909.66	20.00	25,925.00
TR (Travel restriction)	2.29	1.19	0.00	4.00

Table 12. Summary of statistics benchmark for EU airports

Source: Author's calculations

The results of the regression for EU airports are detailed in the third column of Table 9. The R square of this equation is lower than the previous two with a value of 0.054. The P values for all the variables are below 0.02, allowing us to conclude that they all do contribute significantly to the change in the air freight prices. The positive coefficients for the number of COVID cases, ACI and travel restrictions show that an increase in any of these variables is positively correlated with an increase in air freight prices. Inversely, the negative coefficients for market size and capacity growth show that a decrease in any of these variables is positively correlated with a decrease in the air freight prices.

The standard beta allows us to conclude that the greatest contributor to the variation in air freight prices were travel restrictions.

5.7. Discussion of Findings

Looking at the three levels of our analysis, we came to the conclusion that market size has a negative correlation with air freight prices. This is especially relevant in the case of EU airports where we see larger airports witnessing a smaller price increase. The second variable with a negative correlation with air freight price growth is capacity growth. In locations with greater capacity contraction during the pandemic, we see greater growth in air freight prices. The capacity growth variable is of significant relevance in both data sets we analyzed, at the EU country level and the EU airport level. The Air Connectivity Index has a positive correlation to air freight price growth: the more connected a country is, the more the air freight prices increase. The prevalence of COVID cases has a positive correlation with air freight price changes. Our analysis supports these findings at the global level, at the level of EU countries and of EU airports as well. Markets with higher rates of COVID infections seem to have witnessed a greater increase in air freight prices. Finally, travel restrictions are of great significance at the global level and at the level of EU airports, showing a positive correlation with air freight prices (except at the EU country level where it is negative). This positive correlation means that when governments place tighter travel restrictions, the air freight rates increase.

These results confirm several findings that we had identified in the existing literature such as the impact of capacity on revenue management and the impact of changes in the proportion of cargo space from passenger aircraft belly and freighter fleet aircraft on capacity and pricing, in addition to confirming the strong connection between pricing and air freight connectivity.

Our results also provide answers to research questions that had not yet been adequately addressed by the literature such as the behavior of the air freight pricing during time of crises and external stressors. We see this as an important contribution of this thesis to the literature.

As discussed in the literature as well, the air freight market is of great importance to economic growth. It is also an important component of air connectivity which is also directly connected to GDP growth. Therefore, in times of crises, it is important to maintain the stability of the air freight market. As our paper demonstrated, because of the coronavirus pandemic, an unprecedented shock wave hit the air freight industry resulting in large decreases in the market size (but not as important as the decrease in the number of passengers) and large increases in freight prices. For locations where air freight is important, a crisis can greatly influence the prices and the market in general.

To avoid similar scenarios from occurring again, the industry needs to build a certain level of resilience to these external shocks. As per our analysis, the number of COVID cases and the implementation of travel restrictions had a great impact on air freight prices. However, these external factors cannot be controlled by the industry players. The only important factor the air freight industry can control is capacity. Therefore, airlines can build their resilience to future crises by creating a flexible capacity planning system that allows them to absorb any shock that might impact airfreight pricing. As seen in some examples during the coronavirus pandemic, airlines can mitigate changes in capacity by converting older passenger airplanes or having backup freighters ready to deploy. This is especially important as air freight plays an important role in certain industries that are crucial to fighting the pandemic itself such as those involved in PPE and vaccines delivery.

6. Conclusion and Limitations

This thesis looked at the emergence of the COVID-19 pandemic and its sudden impact on the airline industry. We focused on the impact on cargo air freight as it behaved differently from passenger traffic. Whereas passenger demand witnessed continuous decreases, the demand for cargo did not. Combined with an unprecedented decrease in available cargo capacity, this led to historical increase in prices. Throughout 2020, the variations in demand and pricing for air cargo freight were directly impacted by COVID-19-related news, especially in terms of travel restrictions and reduced available capacity.

Our analysis demonstrated a positive correlation between the number of COVID cases, travel restrictions, ACI and the price changes for air freight. The number of COVID cases is relevant at all levels of our analysis, travel restrictions are relevant at the global and EU airport levels and finally air connectivity is especially relevant at the airport level in the case of the European Union. We also demonstrated a negative correlation between capacity growth and air freight prices. A decrease in capacity results in an increase in air freight prices. Both levels of analysis for EU countries and EU airports support this finding. And finally, market size has a negative correlation with the change in air freight prices, but this conclusion only holds for EU airports.

The results of this thesis represent a unique and unprecedented analysis of the changes in air freight prices in times of crises and the variables that drive these changes. It presents the airlines with suggested mitigation strategies to build resilience and lessen the impact of future external shocks that could impact the air freight industry.

The study has some limitations that need to be considered when interpreting the results. The first is the limited number of countries we were able to analyze, because of the absence of pricing data. In our case, we collected the data from the CargoIS CASS data set which is limited to only 72 countries that are unevenly distributed between regions. For example, data for North America and Europe is comprehensive whereas data for other regions, such as Africa and South America, is not. Another limitation is that the pricing data in the 72 countries available in CASS only has limited coverage, focusing mainly on airline carriers and some integrators. Often, full integrators do not use CASS to settle their payments and therefore, their transactions are not reflected in our data set. And finally, in the early days of the pandemic, the traditional air freight shipping process was disrupted, and we saw new processes such as governments chartering airplanes and private charter airlines being used for freight shipments and this is not reflected in the CASS data either.

Finally, capacity data was also challenging to come by, especially for the cargo freight breakdown. Cargo freight can be carried in passenger aircraft and cargo-only aircraft with the volume being carried in each varying greatly depending on the size of the aircraft. Unfortunately, the data on available FTKs was not readily available with the level of granularity this analysis required. We instead opted to use the number of commercial flights as an indicator of the available capacity. Commercial flights include both passenger aircraft and cargo-only aircraft and is a limited proxy for available FTKs. Even with this proxy, the number of commercial flights broken down by country and airport is not available for all the countries we had the pricing information for. Therefore, when analyzing capacity impacts, we focused on European countries and airports as that was the only data set available with the level of granularity we need.

Further research can further investigate the impact of capacity changes of air freight pricing on a more global geographical scope without being limited to European countries. It can also go in detail in terms of capacity changes in passenger aircraft and freighters separately using the actual number of available FTKs.

References

Arvis, J.F., D. DeLaurentis, B. Shepherd, L. Bowers, and S. Tamaskar. Forthcoming. “Measuring Global Air Transport Connectivity: 2008-2012.

Abu-Rayash, A., & Dincer, I. (2020). Analysis of mobility trends during the COVID-19 coronavirus pandemic: Exploring the impacts on global aviation and travel in selected cities. *Energy Research & Social Science*, *68*, 101693. https://doi.org/10.1016/j.erss.2020.101693

Air Cargo News. (2020, July 29). Top 25 cargo airlines 2019. *Air Cargo News*. https://www.aircargonews.net/airlines/top-25-cargo-airlines-fedex-retains-the-top-spot-as-qatar-climbs/

Airbus. (2015). *Airbus Global Market Forecast 2015*. https://espas.secure.europarl.europa.eu/orbis/sites/default/files/generated/document/en/Global_Market_Forecast_2015_Book.pdf

Airports Council International, Europe. (2019). *Airport Industry Connectivity Report*. https://www.aci-europe.org/downloads/resources/aci%20europe%20airport%20industry%20connectivity%20report%202019.pdf

Albers, S., & Rundshagen, V. (2020). European airlines′ strategic responses to the COVID-19 pandemic (January-May, 2020). *Journal of Air Transport Management*, *87*, 101863. https://doi.org/10.1016/j.jairtraman.2020.101863

Arvis, J., & Shepherd, B. (2016). Measuring Connectivity in a Globally Networked Industry: The Case of Air Transport. *World Economy*, *39*(3), 369–385. https://doi.org/10.1111/twec.12363

Arvis, Shepherd. (2013). *Global Connecitivity and Export Performance, World Bank Economic Premise*. https://openknowledge.worldbank.org/bitstream/handle/10986/17026/761890BRI0Box374365B00PUBLIC00EP111.pdf?sequence=1&isAllowed=y

ATAG. (2020). *Employment*. https://aviationbenefits.org/economic-growth/supporting-employment/

Boeing. (2015). *Boeing Market Outlook 2015*. https://www.boeing.com/resources/boeingdotcom/commercial/about-our-market/assets/downloads/Boeing_Current_Market_Outlook_2015.pdf

Boeing. (2020). *Boeing World Air Cargo Forecast 2020-2019*. http://www.boeing.com/resources/boeingdotcom/market/assets/downloads/2020_WACF_PDF_Download.pdf

Budd, L., & Ison, S. (2017). The role of dedicated freighter aircraft in the provision of global airfreight services. *Journal of Air Transport Management*, *61*, 34–40. https://doi.org/10.1016/j.jairtraman.2016.06.003

Burghouwt, G., & Redondi, R. (2013). Connectivity in Air Transport Networks: An Assessment of Models and Applications. *Journal of Transport Economics and Policy*, *47*(1), 35–53.

Cheung, T. K. Y., Wong, C. W. H., & Zhang, A. (2020). The evolution of aviation network: Global airport connectivity index 2006–2016. *Transportation Research Part E: Logistics and Transportation Review*, *133*, 101826. https://doi.org/10.1016/j.tre.2019.101826

Dube, K., Nhamo, G., & Chikodzi, D. (2021). COVID-19 pandemic and prospects for recovery of the global aviation industry. *Journal of Air Transport Management*, *92*, 102022. https://doi.org/10.1016/j.jairtraman.2021.102022

Dutheil, F., Baker, J. S., & Navel, V. (2020). COVID-19 as a factor influencing air pollution? *Environmental Pollution*, *263*, 114466. https://doi.org/10.1016/j.envpol.2020.114466

Feng, B. (2015). *Air cargo operations: Literature review and comparison with practices*. 18.

Flightradar24. (2020, April 16). Cargo flights forming the backbone of COVID-19 relief efforts. *Flightradar24 Blog*. https://www.flightradar24.com/blog/cargo-flights-forming-the-backbone-of-covid-19-relief-efforts/

Flightradar24. (2021, January 1). Commercial flights down 42% in 2020. *Flightradar24 Blog*. https://www.flightradar24.com/blog/commercial-flights-down-42-in-2020/

Forbes. (2020a, April 1). *7 Unusual Ways Aircraft Now Fly Cargo During Coronavirus Outbreak*. Forbes. https://www.forbes.com/sites/willhorton1/2020/04/01/7-unusual-ways-aircraft-now-fly-cargo-during-coronavirus-outbreak/

Forbes. (2020b, April 13). *These Airlines Will Next Remove Seats To Carry Cargo And Medical Supplies On Passenger Aircraft Turned Into Freighters*. Forbes. https://www.forbes.com/sites/willhorton1/2020/04/13/these-airlines-will-next-remove-seats-to-carry-cargo-and-medical-supplies-on-passenger-aircraft-turned-into-freighters/

Forsyth, P., Guiomard, C., & Niemeier, H.-M. (2020). Covid −19, the collapse in passenger demand and airport charges. *Journal of Air Transport Management*, *89*, 101932. https://doi.org/10.1016/j.jairtraman.2020.101932

Goetz, A. R., & Graham, B. (2004). Air transport globalization, liberalization and sustainability: Post-2001 policy dynamics in the United States and Europe. *Journal of Transport Geography*, *12*(4), 265–276. https://doi.org/10.1016/j.jtrangeo.2004.08.007

Hummels, D. (2007). Transportation Costs and International Trade in the Second Era of Globalization. *Journal of Economic Perspectives*, *21*(3), 131–154. https://doi.org/10.1257/jep.21.3.131

IATA. (2016). *Value of Air Cargo, Air Transport and Global Value Chains*. https://www.iata.org/contentassets/307646ccaf10488f9ee240c87d8f72dd/value-of-air-cargo-2016-report.pdf

IATA. (2017). *IATA Annual Review 2017*. https://www.iata.org/contentassets/c81222d96c9a4e0bb4ff6ced0126f0bb/iata-annual-review-2017.pdf

IATA. (2020a). *Air Connectivity, measuring the connections that drive economic growth*. https://www.iata.org/en/iata-repository/publications/economic-reports/air-connectivity-measuring-the-connections-that-drive-economic-growth/

IATA. (2020b). *COVID -19 Updated Impact Assessment*. https://www.iata.org/en/iata-repository/publications/economic-reports/third-impact-assessment/

IATA. (2021). *The Value of Air Cargo*. https://www.iata.org/contentassets/62bae061c05b429ea508cb0c49907c4c/air-cargo-brochure.pdf

ICAO. (2013a). *Strategic Trends in Air Cargo*. https://www.icao.int/Meetings/Regional-Symposia/AC-SP13/Documents/Presentations/S1_1.pdf

ICAO. (2013b). *Worldwide Air Transport Conference*. https://www.icao.int/Meetings/atconf6/Documents/WorkingPapers/ATConf6-wp020_en.pdf

ICAO. (2020, April). *Effects of Novel Coronavirus (COVID-19) on Civil Aviation: Economic Impact Analysis- April 2020*. https://www.icao.int/sustainability/Documents/COVID-19/ICAO%20Coronavirus%202020%2004%2008%20Econ%20Impact.pdf

ICAO. (2021a, January). *Active Fleets by Aircraft Types*. Tableau Software. https://public.tableau.com/views/ActiveFleetsbyAircraftTypes/ActiveFleets?:embed=y&:showVizHome=no&:host_url=https%3A%2F%2Fpublic.tableau.com%2F&:embed_code_version=3&:tabs=no&:toolbar=yes&:animate_transition=yes&:display_static_image=no&:display_spinner=no&:display_overlay=yes&:display_count=yes&:language=en&publish=yes&:loadOrderID=0

ICAO. (2021b, January). *Cargo Flights Comparison by Months. Data Source: ICAO ICADS .For more information or for data / data products requests, please contact us at https://data.icao.int/icads/*. Tableau Software. https://public.tableau.com/views/FlightsandSeatsComparisonbyMonths/FlightandSeatFiguresforRegions?:embed=y&:showVizHome=no&:host_url=https%

3A%2F%2Fpublic.tableau.com%2F&:embed_code_version=3&:tabs=no&:toolbar=yes&:animate_transition=yes&:display_static_image=no&:display_spinner=no&:display_overlay=yes&:display_count=yes&publish=yes&:loadOrderID=0

ICAO. (2021c, January). *Economic Impacts of COVID-19 on Civil Aviation 2021*. https://www.icao.int/sustainability/Pages/Economic-Impacts-of-COVID-19.aspx

John Hopkins. (2021). *Coronavirus COVID-19 John Hopkins Global Dashboard*. https://gisanddata.maps.arcgis.com/apps/opsdashboard/index.html#/bda7594740fd40299423467b48e9ecf6

Kasarda, J. D., & Green, J. D. (2005). Air cargo as an economic development engine: A note on opportunities and constraints. *Journal of Air Transport Management*, *11*(6), 459–462. https://doi.org/10.1016/j.jairtraman.2005.06.002

Kupfer, F., Meersman, H., Onghena, E., & Van de Voorde, E. (2017). The underlying drivers and future development of air cargo. *Journal of Air Transport Management*, *61*, 6–14. https://doi.org/10.1016/j.jairtraman.2016.07.002

Lai, C.-C., Shih, T.-P., Ko, W.-C., Tang, H.-J., & Hsueh, P.-R. (2020). Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and coronavirus disease-2019 (COVID-19): The epidemic and the challenges. *International Journal of Antimicrobial Agents*, *55*(3), 105924. https://doi.org/10.1016/j.ijantimicag.2020.105924

Lloyd's Loading List. (2021, January 6). *Airfreight ends 2020 on a 'relative high'—Lloyd's Loading List*. https://www.lloydsloadinglist.com/freightdirectory/news/Air-freight-ends-2020-on-a-%E2%80%98relative-high%E2%80%99/78203.htm#.YA9H-ehKjIW

Lo, W. W. L., Wan, Y., & Zhang, A. (2015). Empirical estimation of price and income elasticities of air cargo demand: The case of Hong Kong. *Transportation Research Part A: Policy and Practice*, *78*, 309–324. https://doi.org/10.1016/j.tra.2015.05.014

Lu, H., Stratton, C. W., & Tang, Y.-W. (2020). Outbreak of pneumonia of unknown etiology in Wuhan, China: The mystery and the miracle. *Journal of Medical Virology*, *92*(4), 401–402. https://doi.org/10.1002/jmv.25678

Maneenop, S., & Kotcharin, S. (2020). The impacts of COVID-19 on the global airline industry: An event study approach. *Journal of Air Transport Management*, *89*, 101920. https://doi.org/10.1016/j.jairtraman.2020.101920

Ming, W., Zhou, Z., Ai, H., Bi, H., & Zhong, Y. (2020). COVID-19 and Air Quality: Evidence from China. *Emerging Markets Finance & Trade*, *56*(10), 2422–2442. https://doi.org/10.1080/1540496X.2020.1790353

Nobert, Y., & Roy, J. (1998). Freight Handling Personnel Scheduling at Air Cargo Terminals. *Transportation Science*, *32*(3), 295–301. https://doi.org/10.1287/trsc.32.3.295

OECD. (2020, October 15). *COVID-19 and the aviation industry: Impact and policy responses*. OECD. http://www.oecd.org/coronavirus/policy-responses/covid-19-and-the-aviation-industry-impact-and-policy-responses-26d521c1/

Oliver Wyman. (2020). *COVID-19 Impact on Commercial Aviation Maintenance 2020-2030 Fleet and MRO Forecast Update*.

https://www.oliverwyman.com/our-expertise/insights/2020/mar/COVID-19-Impact-On-Commercial-Aviation-Maintenance.html

Oxford University. (2021). *COVID-19 Government Response Tracker*. https://www.bsg.ox.ac.uk/research/research-projects/covid-19-government-response-tracker

Serrano, F., & Kazda, A. (2020). The future of airports post COVID-19. *Journal of Air Transport Management, 89*, 101900. https://doi.org/10.1016/j.jairtraman.2020.101900

STAT TIMES, T. S. T. (2020a). STAT Times. *STAT Times*. https://www.stattimes.com/category/air-cargo/

STAT TIMES, T. S. T. (2020b, May 4). Global air cargo capacity down by 29%, Seabury May 4th, 2020 reports. *STAT Times*. https://www.stattimes.com/news/global-air-cargo-capacity-down-by-29-seabury-reports/

STAT TIMES, T. S. T. (2021, January 27). Global air cargo capacity declines by 16% in the last two weeks: Seabury January 27th 2021 report. *STAT Times*. https://www.stattimes.com/news/global-air-cargo-capacity-declines-by-16-per-cent-in-the-last-two-weeks-seabury-report/

STAT TIMES, T. S. T. (2021, February 9). Global air cargo capacity declines by 17% in the last two weeks: Seabury February 2021 report. *STAT Times*. https://www.stattimes.com/news/global-air-cargo-capacity-declines-by-17-in-the-last-two-weeks-seabury-report/

Suau-Sanchez, P., Voltes-Dorta, A., & Cugueró-Escofet, N. (2020). An early assessment of the impact of COVID-19 on air transport: Just another crisis or the end of aviation as we know it? *Journal of Transport Geography*, *86*, 102749. https://doi.org/10.1016/j.jtrangeo.2020.102749

Sun, X., Wandelt, S., & Zhang, A. (2020). How did COVID-19 impact air transportation? A first peek through the lens of complex networks. *Journal of Air Transport Management*, *89*, 101928. https://doi.org/10.1016/j.jairtraman.2020.101928

Wen, X., Xu, X., Choi, T.-M., & Chung, S.-H. (2020). Optimal Pricing Decisions of Competing Air-Cargo-Carrier Systems—Impacts of Risk Aversion, Demand, and Cost Uncertainties. *IEEE Transactions on Systems, Man, and Cybernetics: Systems*, *50*(12), 4933–4947. https://doi.org/10.1109/TSMC.2019.2930725

Appendices

Appendix 1. Table of CASS countries available

Origin Country Name	Origin Country Code
United Arab Emirates	AE
Argentina	AR
Austria	AT
Australia	AU
Belgium	BE
Bahrain	BH
Brazil	BR
Canada	CA
Switzerland	CH
Chile	CL
China	CN
Colombia	CO
Costa Rica	CR
Cyprus	CY
Czech Republic	CZ
Germany	DE
Denmark	DK
Ecuador	EC
Estonia	EE
Egypt	EG
Spain	ES
Finland	FI
Fiji	FJ
France	FR
United Kingdom	GB
Greece	GR
Hong Kong (SAR), China	HK
Hungary	HU
Indonesia	ID
Ireland	IE
Israel	IL
India	IN
Italy	IT
Jordan	JO
Japan	JP
Kenya	KE
Korea, Republic of	KR

Kuwait	KW
Lebanon	LB
Lithuania	LT
Luxembourg	LU
Latvia	LV
Morocco	MA
Malta	MT
Mauritius	MU
Mexico	MX
Malaysia	MY
Netherlands	NL
Norway	NO
New Zealand	NZ
Oman	OM
Panama	PA
Peru	PE
Philippines	PH
Pakistan	PK
Poland	PL
Puerto Rico	PR
Portugal	PT
Qatar	QA
Romania	RO
Saudi Arabia	SA
Sweden	SE
Singapore	SG
Slovakia	SK
El Salvador	SV
Thailand	TH
Tunisia	TN
Turkey	TR
Chinese Taipei	TW
United States	US
Uruguay	UY
Viet Nam	VN
South Africa	ZA

Appendix 2. Sample of CASS Data

Data Year	Data Month	Origin Country Name	Origin City Name	Origin Airport Code	Destination Country Name	Destination City Name	Destination Airport Code	TY Mkt Weight	TY Mkt Weight Charges per KG (USD)
2017	January	France	Paris	CDG	United States	New York	JFK	xxxx	XX
2017	January	France	Paris	CDG	United States	Atlanta	ATL	xxxx	XX
2018	October	France	Nantes	NTE	United States	Atlanta	ATL	xxxx	XX
2018	October	France	Lyon	LYS	United States	New York	JFK	xxxx	XX
2018	December	France	Strasbourg	SXB	United States	Boston	BOS	xxxx	XX
2018	December	France	Lyon	LYS	United States	Atlanta	ATL	xxxx	XX
2019	August	China	Shanghai	PVG	Germany	Frankfurt	FRA	xxxx	XX
2019	August	China	Beijing	PEK	Germany	Munich	MUC	xxxx	XX
2019	June	China	Shanghai	PVG	Germany	Hamburg	HAM	xxxx	XX

Appendix 3. IATA Regions breakdown

IATA Region	Countries
Asia Pacific	Indonesia, Japan, Korea, Malaysia, Philippines, Singapore
Central & Southern Africa	Kenya, Mauritius, South Africa
Central America & the Caribbean	Costa Rica, Mexico, Panama, Puerto Rico, El Salvador
Europe	Austria, Belgium, Switzerland, Cyprus, Czech Republic, Germany, Denmark, Estonia, Spain, Finland, France, United Kingdom, Greece, Hungary, Ireland, Israel, Italy, Lithuania, Luxembourg, Latvia, Malta, Netherlands, Norway, Poland, Portugal, Romania, Sweden, Slovakia, Turkey
Middle East	United Arab Emirates, Bahrain, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia
North Africa	Egypt, Morocco, Tunisia
North Asia	China, Hong Kong (SAR), Chinese Taipei
North America	Canada, United States
Oceania	Australia, Fiji, New Zealand
South America	Argentina, Brazil, Chile, Colombia, Ecuador, Peru, Uruguay
South East Asia	India, Pakistan, Thailand, Viet Nam

Appendix 4. FlightRadar24 Global commercial flights

Month	2019 Number of flights	2020 Number of flights
Jan	XXXX	XXXX
Feb	XXXX	XXXX
Mar	XXXX	XXXX
Apr	XXXX	XXXX
…….	XXXX	XXXX

Appendix 5. Eurostat Commercial flights by airport and country

Country/Airport	2019-01	2019-02	……	2020-12
Belgium	XXX	XXX	XXX	XXX
Germany	XXX	XXX	XXX	XXX
Estonia	XXX	XXX	XXX	XXX
CDG	XXX	XXX	XXX	XXX
LHR	XXX	XXX	XXX	XXX
FRA	XXX	XXX	XXX	XXX
…..	XXX	XXX	XXX	XXX

Appendix 6. Eurostat database countries

Belgium, Bulgaria, Czechia, Denmark, Germany, Estonia, Ireland, Greece, Spain, France, Croatia, Italy, Cyprus, Latvia, Lithuania, Luxembourg, Hungary, Malta, Netherlands, Austria, Poland, Portugal, Romania, Slovenia, Slovakia, Finland, Sweden, Iceland, Norway, Switzerland, United Kingdom, Montenegro, North Macedonia, Albania, Serbia, Turkey

Appendix 7. Airport to city combinations

Origin Country Name	Origin City Name	CASS Origin Airport Name	CASS Origin Airport Code	Euro Stat Airport Name
Austria	Linz	Linz-Blue Danube	LNZ	LINZ airport
Austria	Vienna	Vienna-Schwechat Intl	VIE	WIEN-SCHWECHAT airport
Belgium	Brussels	Brussels-Brussels Airport	BRU	BRUSSELS airport
Belgium	Brussels	Brussels-Brussels S. Charleroi	CRL	CHARLEROI/BRUSSELS SOUTH airport
Belgium	Liege	Liege-Airport	LGG	LIEGE airport
Switzerland	Zurich	Zurich-Zurich Airport	ZRH	ZURICH airport
Czech Republic	Prague	Prague-Ruzyne	PRG	PRAHA/RUZYNE airport
Germany	Frankfurt	Frankfurt-International	FRA	FRANKFURT/MAIN airport
Germany	Frankfurt	Frankfurt-Hahn	HHN	FRANKFURT-HAHN airport
Germany	Munich	Munich-International	MUC	MUENCHEN airport
Denmark	Billund	Billund-Billund	BLL	BILLUND airport
Denmark	Copenhagen	Copenhagen-Kastrup	CPH	KOBENHAVN/KASTRUP airport
Estonia	Tallinn	Tallinn-Lennart Meri	TLL	LENNART MERI TALLINN airport
Spain	Barcelona	Barcelona-Airport	BCN	BARCELONA/EL PRAT airport
Spain	Madrid	Madrid-Adolfo Suarez-Barajas	MAD	ADOLFO SUAREZ MADRID-BARAJAS airport
Finland	Helsinki	Helsinki-Helsinki-Vantaa	HEL	HELSINKI-VANTAA airport
France	Lyon	Lyon-St-Exupery	LYS	LYON SAINT-EXUPERY airport
France	Paris	Paris-Charles de Gaulle	CDG	PARIS-CHARLES DE GAULLE airport
France	Paris	Paris-Le Bourget	LBG	PARIS-LE BOURGET airport
France	Paris	Paris-Orly	ORY	PARIS-ORLY airport
United Kingdom	London	London-Gatwick	LGW	LONDON GATWICK airport
United Kingdom	London	London-Heathrow	LHR	LONDON HEATHROW airport

United Kingdom	London	London-Luton	LTN	LONDON LUTON airport
United Kingdom	London	London-Stansted	STN	LONDON STANSTED airport
Greece	Athens	Athens-Eleftherios Venizelos	ATH	ATHINAI/ELEFTHERIOS VENIZELOS airport
Hungary	Budapest	Budapest-Liszt Ferenc Int'l	BUD	BUDAPEST/LISZT FERENC INTERNATIONAL airport
Ireland	Dublin	Dublin-International	DUB	DUBLIN airport
Italy	Florence	Florence-Peretola	FLR	FIRENZE/PERETOLA airport
Italy	Milan	Milan-Bergamo/Orio al Serio	BGY	BERGAMO/ORIO AL SERIO airport
Italy	Milan	Milan-Linate	LIN	MILANO/LINATE airport
Italy	Milan	Milan-Malpensa	MXP	MILANO/MALPENSA airport
Italy	Rome	Rome-Ciampino	CIA	ROMA/CIAMPINO airport
Italy	Rome	Rome-Fiumicino	FCO	ROMA/FIUMICINO airport
Lithuania	Vilnius	Vilnius-International	VNO	VILNIUS/INTERNATIONAL airport
Luxembourg	Luxembourg	Luxembourg-Luxembourg	LUX	LUXEMBOURG airport
Latvia	Riga	Riga-International	RIX	RIGA airport
Netherlands	Amsterdam	Amsterdam-Schiphol Airport	AMS	AMSTERDAM/SCHIPHOL airport
Norway	Oslo	Oslo-Gardermoen	OSL	OSLO/GARDERMOEN airport
Poland	Warsaw	Warsaw-Frederic Chopin	WAW	WARSZAWA/CHOPINA airport
Poland	Wroclaw	Wroclaw-Nicolaus Copernicus	WRO	WROCLAW/STRACHOWICE airport
Portugal	Lisbon	Lisbon-Airport	LIS	LISBOA airport
Portugal	Porto	Porto-Francisco Sa Carneiro	OPO	PORTO airport
Romania	Bucharest	Bucharest-Henri Coanda	OTP	BUCURESTI/HENRI COANDA airport
Sweden	Malmo	Malmo-Airport	MMX	MALMO airport
Sweden	Stockholm	Stockholm-Arlanda	ARN	STOCKHOLM/ARLANDA airport
Slovakia	Bratislava	Bratislava-M.R. Stefanik	BTS	BRATISLAVA/M.R.STEFANIK airport
Turkey	Istanbul	Istanbul-Ataturk	ISL	ISTANBUL/ATATURK airport
Turkey	Istanbul	Istanbul-Istanbul Airport	IST	ISTANBUL/ISTANBUL HAVALIMANI airport
Turkey	Istanbul	Istanbul-Sabiha Gokcen	SAW	ISTANBUL/SABIHA GOKCEN airport

Appendix 8. Sample data for IATA's Air Connectivity Index

Country	Air connectivity score 2019	Global Ranking 2009
United States	8,130,508	1
China	5,368,567	2
Japan	1,622,029	3
India	1,247,297	9
Germany	924,731	5
United Kingdom	916,314	4
Indonesia	838,855	13
Spain	793,379	6
Thailand	696,422	15
Italy	607,532	7

Appendix 9. Sample data for Airports Council International Air Connectivity Index

Airport Code	Airport Name	Direct ACI	Indirect ACI	Airport ACI
LNZ	Linz	45	329	373
HHN	Hahn	86	1	87
BTS	Bratislava	168	41	209
WRO	Wroclaw	264	815	1,079
FLR	Florence	318	1,938	2,256
BLL	Billund	354	1,549	1,903
TLL	Tallinn	383	1,368	1,751
VNO	Vilnius	400	1,044	1,444
CRL	Charleroi	530	96	626
LUX	Luxembourg	560	1,945	2,505
BGY	Bergamo	820	99	919

Appendix 10. Sample data of OxCGRT

Month	Country	Average travel restriction code	Max travel restriction code	Min travel restriction code
Dec 2020	Vietnam	3.55	4	3
Dec 2020	Uruguay	3.35	4	3
May 2020	Brazil	4.00	4	4
May 2020	Canada	4.00	4	4
Jul 2020	Chile	3.00	3	3
Jul 2020	Croatia	2.45	3	2
Oct 2020	Czechia	3.00	3	3
Oct 2020	Egypt	1.52	2	1
Oct 2020	Hong Kong	4.00	4	4