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Solving the mystery of discrepancies and double counting in air cargo through demand and supply big data analysis

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Abstract: This paper estimates and analyses the air cargo demand and supply imbalances between large geographical regions based on newly collected demand and supply data. Due to the need for more data for academics and the industry, and the lesser research interest compared to its passenger counterpart, limited empirical research on air cargo market dynamics has been conducted. Live flight and aircraft data were collected for five consecutive years to reconstruct the air cargo network and capacity. Air cargo sales tonnes data were collected and introduced as these data eliminate double counting of transfer route volumes. Both datasets were used and compared to analyse the air cargo trade imbalances. The major findings indicate an imbalance in demand on most of the 110 studied region pair combinations. The supply data indicate a high imbalance for freighter capacity, a relatively smaller imbalance for integrator capacity and a limited imbalance for the wide-body belly capacity. The data indicate that the Middle East, Northeast Asia, Russia, Central Asia, and Central America regions are all transfer or in-transit regions where a large amount of cargo passes through. However, limited cargo volumes originate or find their final destination here. Although the general assumption indicates that air cargo supply follows air cargo demand, imbalances between demand and supply in opposing directions were found for several region pairs. To the best of our knowledge, this paper is one of the first academic sources to introduce data analysis based on sales tonnes. This research assists academics and the industry in getting a better understanding of the current air cargo market dynamics. It also provides a base to enhance future air cargo market research, analysis and forecasting.
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1. Introduction

With 60.9 million tonnes of goods transported in 2021, less than 1% of world tonnes are estimated to be carried by air cargo. Because of the high value of these goods, they represent about 35% of the value of goods shipped globally (Boeing, 2022). The increase in air cargo rates to record-breaking levels attracted much interest from inside and outside the industry. Other than the bi-directional nature of air passenger flows, air cargo tends to move from manufacturing to distribution centres or from production to consumption centres causing imbalances in air cargo flows (Zhang and Zhang, 2002). Those imbalances are especially important for the planning departments of airlines operating freighter aircraft as those aircraft often perform triangular or multisector routes to cope with those imbalances (Bombelli et al., 2020). Another way airlines cope with air cargo demand imbalances is by applying a hub and spoke network. By using a hub and spoke system, airlines can consolidate air cargo flows in their hub to optimise their capacity and increase their revenues. Although air cargo was considered a by-product for passenger airlines in the past, the COVID-19 pandemic made those airlines rethink their cargo activities to survive. One of the main problems in air cargo research is the shortage of publicly available air cargo data. Although some data published in reports by major institutions like IATA[1], ICAO[2] or Boeing[3] are available, their data are generally published on an aggregated market or region level. Although comprehensive disaggregated data is often published by organisations like EUROSTAT or the US Bureau of Transport Statistics for a certain region, collecting disaggregated

[1]IATA publishes monthly Air Cargo Market Analyses and quarterly Cargo Chartbooks at their IATA economics publications: https://www.iata.org/en/publications/economics/. IATA also published the IATA World Air Transport Statistics (WATS) yearly. Unfortunately, those statistics are not publicly available.

[2]Although ICAO collects and provides data in their DATA+ tool, which is not publicly available, they publish aggregated data in their Annual Reports of the Council: https://www.icao.int/about-icao/Pages/annual-reports.aspx.

[3]Boeing publishes bi-annual World Air Cargo Forecasts (WACF) and commercial market outlooks: https://www.boeing.com/commercial/market.

data for other regions or combining those datasets to build a comprehensive dataset comprising all regions and countries can be rather time-consuming.

This paper's comprehensive actual flow database is constructed through intensive data collection. Flight data from three main flight-tracking websites were collected, cleaned and combined into a database. The database consists of data from January 2018 until December 2022. Although data from flight tracking websites were already sources in previous research (Bombelli, 2020; Bombelli et al., 2020; Malighetti et al., 2019a and 2019b), it will be the first time data from three different sources and over five years were collected and combined. Combining heterogeneous datasets can be a rather tedious task as it might cause challenges. The main challenges found were the different features published by the different sources, time zone deviations, mismatches in departing and arrival timings, and missing data. We addressed those problems by working with features that were available for all rows, transferring all rows to the same time zone, working with time buckets, and removing rows that were not useful due to the missing data. Afterwards, we compared the Available Cargo Tonnes (ACT) of 2021 of our comprehensive database with the ACT numbers IATA published. Next to introducing a comprehensive flight database, we also introduce, to the best of our knowledge, the first international sales tonnes data into the academic literature. Sales tonnes data are the actual tonnes sold and transported by air without double counting due to transfers or in transit. Both datasets were used to estimate the air cargo demand and supply on industry and region-to-region levels. Different types of data originating from different sources are compared to indicate the importance of understanding which data types are used. After providing a market overview of air cargo demand, supply, and rates, a region-to-region analysis for the 2022 data is conducted to estimate the amplitude of the air cargo sales tonnes flows and imbalances between different regions. The same analysis is conducted for the supply side for wide- body belly capacity, dedicated freighter capacity and integrator capacity.

The rest of the paper is organised as follows. Section 2 provides an overview of the current air cargo demand studies, supply studies, and data sources used in the academic research. Section 3 presents the methodology and data collection process. Section 4 gives an overview of both air cargo demand and air cargo supply on an aggregate level and discusses data problems of different sources and problems when comparing different sources. Section 5 focuses on the air cargo demand and supply imbalances separately and compares both imbalances. Section 6 provides conclusions, limitations and recommendations for future work.

2. Literature review

Although air cargo studies are generally considered underrepresented in the academic literature compared to their passenger counterparts, air cargo research has received growing interest in the last fifteen years. Air cargo studies can be classified into four broad categories (Yu and Zou, 2022); (1) competition and connectivity of airports in the air cargo market, (2) air cargo market structure and airline competition, (3) air cargo operations, and (4) analysis and estimation of air cargo demand and its relationship with economic or trade growth. This research will focus on the second aspect, particularly the air cargo market structure, and on the fourth aspect, the analysis of air cargo demand. Of the main aspects that will be analysed in this paper, air cargo demand is the most extensively discussed in the current literature.

2.1. Air cargo demand

While there is a general agreement that air cargo transport, as cargo transport in general, is the result of economic activity and, therefore, an operationally derived demand (Rodrigue, 2006; Kupfer et al., 2017), there are some discrepancies in how air cargo demand is derived. Grin (1998) discusses that air cargo demand can usually be seen as a derivate of transport, which in itself is a derivate of trade. Meanwhile, Holloway (2008) states that air cargo depends on the underlying demand for goods requiring rapid transportation as well as on the costs and benefits of air cargo compared to alternative modes of transportation. Those discrepancies are present in defining how air demand can be derived and determining the underlying parameters for air cargo forecasting. Most air cargo demand studies focus on the relationship between air cargo and economic growth (Alici and Akar, 2020). The Gross Domestic Product (GDP), an indicator of economic development, is one of the most studied determinants for air cargo by academic researchers. Kasarda and Green (2005) study the empirical relationships between air cargo, trade, and GDP per capita to quantify air cargo's role in economic development. Wadud (2013) simultaneously forecasted demand for passenger and cargo at the Shahjalal International Airport using GDP, national price levels, and oil prices as determinants for the demand. Morrell and Klein (2018) identified GDP, international trade, oil prices, exchange rates, interest rates, and globalisation as key variables for forecasting future air cargo demand.

Although GDP is a good indicator of the growth and health of an economy, the role of GDP in air cargo demand forecasting can be questioned (Kupfer et al., 2011). Last decades the development of the importance of services in GDP caused the relationship between GDP and air cargo to become less straightforward. While services made up 53% of the world GDP in 1970, this number increased to 64.4% in 2021. High-income countries generally have a higher share of services in their GDP, for example, a share of 71.8% in high-income countries versus 39.1% in low-income countries (Worldbank, 2022). As a result, global value added is increasingly being generated by services rather than economic activities that may generate air cargo. Kupfer et al. (2017) propose to use merchandise trade and share of manufactures in merchandise trade instead of GDP and industrial production, which is often used to represent the link between economic activity and transport and can also be considered a weak indicator for air cargo. Other authors (Hamal, 2013; Lakew and Tok, 2015; and Alexander and Merkert, 2021) also forecasted air cargo demand at airport, regional, and country levels without using GDP as an indicator.

Boeing (2022) states that although air cargo accounts for less than 1% of the world's trade tonnes, it is responsible for about 35% of the value of all globally shipped goods, indicating the high value of these goods. Air cargo commodities can be classified in different ways and product types based. The IATA classification, which divides air cargo into general and special cargo, is widely used in the industry. Special cargo are goods that, due to their nature, weight, dimensions, and/or value, may have specific requirements, including packaging, labelling, documentation, and handling through the transport chain. The transport of those goods is addressed through specific regulations that must be followed when preparing, offering, accepting, and handling this cargo (IATA, 2023). Special cargo is subdivided into the following products; valuable, pharmaceuticals and temperature-controlled, live animal, vulnerable, dangerous, and perishables products. One of the classification's flaws is the large allocation to general cargo. Another classification for air cargo commodities was made by Doganis (2010), classifying air cargo into manufacturing goods, machinery and transport equipment, and a remaining part consisting of a variety of different commodities, among which fresh foods, medical and pharmaceutical goods, as well as chemicals, are of particular importance. Each of the three classes comprises one-third of the worldwide air cargo tonnes. In addition to those two classifications, each country's statistical and data embodiments have their classification of air cargo products, making data source comparison difficult. Many authors (Holloway, 2008; Doganis, 2010; Shaw, 2016) prefer to segment the air cargo market based on the shipper's motivation and journey urgency rather than considering individual commodities. They identified four key commodity types in increasing order of price sensitivity: emerging freight, high-value freight, routine perishables freight, and routine non-perishable freight. Whatever classification system is used, there are differences in air cargo flows when comparing regions, countries, and airports, as indicated by Boeing's world air cargo market forecast.

According to Zhang and Zhang (2002), economic activity in the importing region drives cargo movement from manufacturing to distribution centres or from production to consumption centres. Different levels of commercial activity at either end of a route can amplify directional imbalances in cargo tonnes, and commodities carried, mainly if the two points are at different stages of the economic cycle (Holloway, 2008). This effect of the economic activity in the importing region and the various stages of the economic cycle also explains the different types of products transported by air on a region, country, and route level. On the Europe-East Asia route, for example, 27% of cargo on the East Asia-Europe leg consists of computers, office, communications, and professional equipment. In comparison, those goods represent only 8% of the air cargo flown on the Europe to East Asia leg. Both Boeing (2022) and Morrell and Klein (2018) provide an overview of the main imbalances in air cargo demand. The data they used is actual tonnes carried data and includes transfer and in-transit data. By including this data type, they analyse the imbalanced carried flows rather than the actual import and export imbalance between regions.

2.2. Air cargo supply

Airlines have different strategies when it comes to cargo operations. Generally, airlines handling cargo can be divided into integrators, freighter carriers, combination carriers, and passenger carriers (Li et al., 2012). Integrators (e.g., DHL, UPS, and FedEx) sell capacity to shippers directly through direct market channeling. Through indirect market channeling, they sell their excess capacity to freight forwarders. Freighter carriers are airlines dedicated to transporting air cargo (e.g., Cargolux). Those airlines only operate dedicated freighter aircraft and sell their capacity through indirect market channeling. Combination carriers only transport cargo with passenger aircraft (e.g., British Airways) or with both passenger and dedicated freighters aircraft (e.g., Lufthansa). Passenger airlines focus on passenger operations and do not transport cargo (e.g., Ryanair). (Feng et al., 2015). Historically, air cargo was considered a by-product of passenger transport. In the last twenty years, many traditional carriers have considered it an instrument for profit maximisation (Kupfer et al., 2012). Focusing simultaneously on cargo and passengers can enable multiple benefits for passenger carriers (Gangwani, 2015). Air cargo allows passenger carriers to offer routes that are not commercially viable on passenger demand alone but also enables them to offer higher frequencies on their existing routes. Due to the marginal costs of transporting cargo into the belly hold of passenger aircraft, carriers can increase and diversify their revenue streams and margin per route.

Cargo can be transported on different types of aircraft. The most common breakdown in academic literature divides aircraft into passenger, freighter, combi, and convertible aircraft. Most aircraft are passenger aircraft transporting passengers on the main deck and luggage and cargo on the lower deck. Freighter aircraft only transport cargo and can be either dedicated or converted. Dedicated freighters are aircraft designed from the beginning only to transport cargo, while converted freighters are passenger aircraft converted to freighter aircraft. Due to previous passenger requirements, the last type has some payload restrictions that dedicated freighters do not have. Convertible aircraft are limitedly built and can switch the number of seats on the main deck to allow more or less cargo payload. Although those aircraft were famous in the past, today, they can be considered neglectable due to the minimal number of those aircraft in the overall fleet. In the academic literature, the focus can be on all aircraft types (Kupfer et al., 2011; Morrell and Klein, 2018; Bombelli et al., 2020), freighter aircraft (Budd and Ison, 2017), or passenger aircraft (Merket and Ploix, 2014).

Both passenger and freighter aircraft have their benefits and limitations. First, freighters are generally used in markets with higher demand for cargo than passengers and markets with an imbalance between incoming and outgoing cargo (Kupfer et al., 2011). Second, freighter aircraft are used to transport cargo that, due to its dimensions or hazardous characteristics, is not suitable to be transported in passenger aircraft (Merket and Ploix, 2014). Although there is a market for hazardous and oversized cargo, only 5 to 15% of all air cargo is bounded to be transported on freighter aircraft (Boos, 2015). Third, freighter aircraft are particularly well suited for transporting high-value goods because they provide highly controlled transport, direct routing, reliability, and unique capacity considerations (Boeing, 2017). Last, the capacity of freighter aircraft is fixed, which is different for belly capacity with a varying capacity to short-term variations in passenger numbers and luggage weight and sizes (Amaruchkul et al. 2010). This guaranteed capacity offers airlines and consignors better flown-as- booked rates (Crabtree, 2014). The belly capacity of passenger aircraft is smaller than the cargo capacity of freighter aircraft. Therefore, the marginal costs of filling up this capacity are generally only one-third of the cost of filling up a freighter capacity (Morrell and Klein, 2018). The lower marginal costs make belly capacity particularly suitable for air cargo products with lower yields, like some types of perishables and general cargo.

In the last couple of years before the COVID-19 pandemic, around half of the air cargo was transported on freighter aircraft, and the other half was transported as belly cargo on passenger aircraft. As discussed in the previous section, different levels of commercial activity at either end of a route can amplify directional imbalances in cargo tonnes. This uneven spatial nature of air cargo demand is often referred to as the backhaul problem (Budd and Ison, 2017). Although the backhaul problem causes airlines to struggle with finding enough volume to fill their capacity on some legs, airlines operating freighters often fly triangular and multisector routes to cope with this problem. Bombelli et al. (2020) presented a complex network analysis of the air transport network using the air cargo perspective. They found that the percentages of origin-destination airport pairs served in both directions and in a single direction are 77 and 23%, respectively. Because of the bi-directional nature of passenger traffic, belly capacity is bound to fly both legs of the same route, making the backhaul problem even more significant for belly capacity. Due to the backhaul problem, the higher capacity uncertainty of belly capacity, and the passengers' luggage, air cargo weight load factors are lower on belly capacity than on freighter capacity (Morrell and Klein, 2018). Following IATA (2021), the all-cargo flight freight load factor was around 65%, while the mixed flight freight load factor was around 36%. Regarding integrator network analysis, Bombelli (2020) found very imbalanced air cargo flows for FedEx and UPS towards their hubs in MEM and SDF, and more balanced flows for the DHL network from November 2019 till June 2020.

Another way airlines, and especially Middle Eastern Carriers, cope with the backhaul problem is to employ a hub and spoke network using their strategically located hub to feed and defeed freighter and belly capacity (Budd and Ison, 2017). Hubs are even more critical for air cargo than for air passengers. While the top ten passenger hubs account for only one-third of global passenger traffic, the top ten cargo hubs account for two-thirds of global freight traffic (Holloway, 2008). Integrators atypically operate from a hub and spoke network in North America, but Malighetti et al. (2019b) also found hub and spoke networks for the European market. Malighetti et al. (2019a) studied the air transport networks of global integrators in the more liberalised Asian air cargo industry and found that integrators operate extensive multi- hub networks in the Asian market as well. Air cargo has a much larger catchment area than the air passenger side. The larger catchment area allows airlines to feeder their flight by trucking. Especially in Europe, where trucking distances are relatively small and good infrastructure is present, trucking is common. Although it is common, Baier et al. (2021) argue that a quantitative approach to automate a clear-cut catchment area of airports for air cargo is complex due to the unprecise trucking networks processing airfreight from and to airports. Although freighter aircraft carry around half of the total air cargo, their role has often been questioned and examined. Following the financial crisis in 2008/2009, there was overcapacity in the market, causing airlines to ground and retire freighter aircraft. In times of crisis and overcapacity, airlines switch from freighter aircraft to belly-capacity aircraft (Kupfer et al., 2017). The overcapacity was present due to the economic downfall causing lower air cargo volumes to be transported, new passenger aircraft with higher belly hold capacity, a modal shift towards cheaper sea shipping, and an increase in international trade protection measures restricting cross-border trade (Budd and Ison, 2017). Although new aircraft have higher payloads for air cargo due to increased size and fuel efficiency gains, their impact on overcapacity is not yet significant (Boeing, 2017). Although the general grounding and retirement of freighters in this period, in some world regions, the demand for freighters kept growing (Budd and Ison, 2017). In times of crisis and overcapacity, airlines switch from freighter aircraft to belly-capacity aircraft. Although many freighter aircraft were not expected to have a future any longer, the COVID-19 pandemic caused freighter aircraft to be a crucial asset in transporting air cargo. Ageing cargo aircraft were being taken out of storage and returned to service (Macário and Van de Voorde, 2022).

2.3. Air cargo data sources

Publicly available air cargo data for academic purposes are scarce. One of the reasons for this scarcity can be found in the confidentiality of the data and the competition for the data (Bombelli et al. 2020). The problem is even more severe when it comes to integrator data (Lakew, 2014 and Malighetti et al., 2019a). Gong et al. (2017) claim that the shortage of comprehensive data on price and traffic volumes at the route or airline level is one of the main reasons air cargo is lesser developed than its passenger counterpart. This conclusion was also found by Wei (2006), who indicated that the unavailability of sufficient, accurate and consistent data in the air cargo industry is one of the reasons for the lack of in-depth air cargo research. Although there is a scarcity of publicly available aviation market data for academic research, some nuances can be made.

First, large institutions and companies like IATA, Boeing, and the ICAO often collect and make publicly aggregated market data available. IATA publishes the IATA World Air Transport Statistics (2021) on a yearly level providing information on air cargo demand, capacity and payload levels. One of the shortcomings of this database, other than the unavailability of public access, is the level of aggregation of the data. Although a distinction is made between international, domestic, scheduled, charter, and all cargo flights, the data is aggregated per airline per year. This makes the data suitable for more aggregated research but less suitable for more disaggregated analyses, especially for origin-destination research. Publicly available air cargo data for those three sources do not come in the form of datasets but can rather be found in reports. One of those reports is the monthly Air Cargo Market Analysis from IATA (2014-2023). Those monthly reports provide an update on the current situation of the air cargo market and data on air cargo demand and supply on an international and main region level. One of the shortcomings of the data is that those reports often publish percentage change data rather than absolute numbers. However, some reports also include actual numbers, which makes it possible to use those percentages to estimate the missing absolute numbers. The same can be done for IATA's quarterly Air Transport Chartbook reports (IATA, 2015-2023) and for ICAO's Annual Reports of the Council (ICAO, 2008-2021). Next to the time-intensive task of analysing all those reports, the methodology of how the data behind those reports are collected is often unclear. Next to both sources, Boeing publishes its bi-annual World Air Cargo Forecast and its commercial market outlooks (Boeing, 2022). Because only the latest report is published on the Boeing website, older reports are often more difficult to obtain. Unlike the IATA and ICAO reports, Boeing published more absolute figures in its report making the reports more convenient to use. However, much detailed or older data is still hidden in graphs and percentages, which can be a shortcoming if you are looking for those specific data.

Second, disaggregated data is also often available, but the task of collection and cleaning is time-consuming. Disaggregated air cargo demand data is often published in countries' databases and can be accessed through a web portal or an application programming interface (API). Although looking for the data is not necessarily time-consuming, cleaning the data due to inconsistencies between sources, methodologies, data types, and data features is. Disaggregated air cargo supply data is often more hidden than its demand counterpart. Wei (2006) discussed that the problem of inconsistencies between disaggregated data sources and not knowing which data source is the most accurate or consistent is one of the main problems in air cargo data. Wei (2006) explored the available data sources and databases related to air cargo studies to investigate what data are available and what analysis can be made based on current data sources to study air cargo activity at a state level, specifically in California. Eight major, mainly North American data sources were studied and explained. He found that the data of those sources either came from airlines, airports, or shippers who each report data collected from their own perspective. The airline data mainly originates from the US Bureau of Transportation Statistics (BTS) who collects and compile data from certified air carriers on Schedules T-100 and T-3. Airport data is mainly published by airports themselves and by the Airport Council International (ACI), who publishes the Annual Worldwide Airport Traffic Report based on a survey of large airports worldwide. The last type of data, originating from shippers and logistics companies, is obtained by the Commodity Flow Survey (CFS). CFS is a survey of shipments by domestic establishments in manufacturing, wholesale, mining and selected other industries. Because all sources collect data considering their own perspectives, it is not surprising that the published data of the above sources are inconsistent. A second problem between those databases is that some important features are missing, such as the value of the goods transported, the routing of the goods, the production location, the final destination, etc. The last problem is with the CFS database. Although Wei (2006) considered the CFS database to be the most 'useful' as the database classifies the data of the flow of types of goods and materials by mode of transport, the database is not published yearly. The latest publication that could be found was of 2017.

Table 1 provides an overview of large data sources used in the academic literature. With large data sources, we refer to sources that cover the whole world, like the Official Aviation Guide (OAG) database or the Airport Council International (ACI) database, or data sources that cover a large region, like the US Bureau of Transportation Statistics (BTS) or Eurostat, the database of the European Union and its partnering countries. Datasets only covering large regions of certain continents, like BTS or Eurostat, are often used to conduct case studies or to analyse certain routes, regions, or sub-regions (Bowen, 2012 and Morrell and Klein, 2019). Bowen (2012) used the BTS data of 2010 to assess the network evolution of both FedEx and UPS. Although the database is relatively complete, he argued that one of the shortcomings was that there was no data on integrators' traffic carried on partner airlines which could slightly affect their results. A database used in air cargo tis the OAG database. The OAG database consists of historical published flight schedules, excluding actual non-scheduled flights and non-IATA members' flights (Heinits and Meincke, 2013). Although charter flight takes up around 5% of the international air cargo capacity (Boeing, 2009-2021), the impact of the missing charter data in the OAG S is yet unsure. The problem of missing charter and non-scheduled flights is not only a shortcoming of the OAG but also of the Seabury Consulting dataset. Bombelliet al. (2020) discussed that the Seabury Consulting dataset was missing integrator, LATAM, charter and other non-scheduled flights. The dataset they received from Seabury Consulting contained origin-destination data for 2014. They collected the missing data to fill the gap using the flight tracking website FlightRadar24. Although flight tracking websites have been around for quite some time, it is only recently that authors like Malighetti et al. (2019a and 2019b), Bombelli et at. (2020) and Bombelli (2020) started collecting actual flight data for air cargo purposes, mainly network analyses. Although those types of data can be very useful for analysing market dynamics, competition analyses, route scheduling problems etc. as they are very disaggregated, the collection of such data is highly time-consuming as the data is often only available for one week.

Table 1: *Major air cargo data sources used in publications.*

Reference	Objective	Data Source	Description	Constraints
Bowen (2012)	Assessment of the network evolution of FedEx and UPS	US Bureau of Transportation Statistics (BTS)	Monthly reported domestic and international airline data for certified U.S. air carriers and data of foreign carriers having at least one service point in the United States or its territories. Data for 2010.	No data are recorded for sectors that begin and end outside the US. No data on integrator traffic carried on partner airlines.
Heinitz and Meincke (2013)	Construct a multistep, twofold capacity-restrained itinerary-based demand assignment algorithm.	Official Aviation Guide (OAG)	Published recent and historically scheduled flights. Sample data for a week in 2007.	The dataset excludes the actual non-scheduled flights and flights of non-IATA airlines, such as integrators.
Song and Yeo (2017)	Analysis of the air transport network using the social network analysis approach.	Airport Council International (ACI)	Data on the top 20 airports in 2016 based on passenger, cargo, and movements.	No data is publicly available outside the top 20.
Song and Yeo (2017)	Analysis of the air transport network using the social network analysis approach.	Web pages of airlines alliances	Reconstruction of the route network in March 2017, taking into account 1,060 airports in 173 countries. In total, 5,580 routes were constructed.	Exclusion of non-alliance members. Focus on international rather than domestic routes.
Morrell and Klein (2019)	Providing an overview and status of the air cargo industry	Eurostat	Overview of traffic between origin-destination airports where at least one airport is located in the European Union or one of the partnering countries. Overview of data from 2006 until 2016.	None
Morrell and Klein (2019)	Providing an overview and status of the air cargo industry	BTS	See Bowen (2012). Data for 2015.	See Bowen (2012)
Morrell and Klein (2019)	Providing an overview and status of the air cargo industry	Boeing WACF	Overview of aggregated air cargo flows between pre-defined major regions based on 2015 data.	Data is only available for the major region pairs, neglecting smaller air cargo flows.
Morrell and Klein (2019)	Providing an overview and status of the air cargo industry	IATA WATS	Overview of aggregated air cargo carried per airline in 2016.	Data is not publicly available
Malighetti et al. (2019a)	Analysis of the Asian air integrator networks by graphical analysis and complex network metrics.	FlightRadar24	Data on flights “departing from” and/or “arriving at” one of the airports located in Asia. Sample data for one week in 2015.	Not possible to investigate a temporal evolution of the network since the data set merely provides a picture of the networks’ structures.
Malighetti et al. (2019b)	Network analysis of the integrators in Europe	FlightRadar24	See Malighetti et al. (2019a)	See Malighetti et al. (2019a)
Bombelli et al. (2020)	Complex network analysis of the air transport network using the air cargo perspective	Seabury Consulting flight schedule database	List of airports characterised by a yearly international cargo throughput of 5,000 tonnes or higher + the yearly frequency per aircraft type for all OD airport pairs. Dataset was based on 2014 data.	Integrator, LATAM Cargo, narrow body passenger, charter and other non-scheduled operation data excluded
Bombelli et al. (2020)	Complex network analysis of the air transport network using the air cargo perspective	FlightAware	All recorded departures were collected for each airport part of the air cargo transport network. Data was collected from June 2019 until January 2020.	Only data for seven months due to time limitation
Bombelli (2020)	Analysis of the global networks of integrators using network science	Flightradar24 and FlightAware	Pre-selected a set of 336 airports deemed relevant from a cargo perspective (i.e., with an annual cargo throughput in 2014 greater or equal to 5000 tonnes. Data were collected from November 2019 until June 2020.	Ruling out lower-tier airports Temporal holes due to not starting the data retrieval process at the correct time

Due to the time intensity of the data collection, the authors only collected the data from one week to a few months. Although taking samples might be interesting to get a picture of a certain moment in time, it would be more interesting to analyse market dynamics to better understand those pictures' evolution. Although this paragraph provides a basic overview of data sources used in air cargo research, there is a need for more in-depth analyses of air cargo sources to understand their benefits and shortcomings. Next to understanding those data sources and their differences, there is also a need to find or construct a benchmark database against which other sources can be compared.

2.4. Summary and contribution

In summary, the current academic research on air cargo market dynamics needs to be enhanced. Although some research has already been conducted on air cargo demand and supply separately, much research is yet to be done on a combined analysis of both demand and supply. One of the main problems in the current literature regarding air cargo is the need for more comprehensive data, which is required to perform more in-depth analyses to better understand air cargo market dynamics. The contribution of this paper is twofold: (1) New air cargo demand and supply data is collected from various sources and combined into one comprehensive dataset. (2) The dataset is used to analyse both air cargo demand and supply imbalances on a region-to-region level separately and simultaneously.

3. Methodology and data description

3.1. Methodology

This research uses an inductive approach to conduct an air cargo data-driven market analysis on the global market and the main trade lines. Air cargo-related market data on the network, demand, supply, and aircraft will be sourced from multiple sources on a disaggregated market level. The data will be jointly analysed to provide an overview of the air cargo market and identify patterns and relations. The inductive approach is chosen for two reasons. First, air cargo market research is scarce, and few theories have yet to be developed. The inductive approach allows us to start with market observations and develop new theories and insides through analysis and pattern recognition to fill this gap in the current literature. Second, the air cargo market is complex, with different sub-market characteristics. The inductive approach allows us to start with disaggregated data to better understand those complex dynamics before going to a more aggregated level.

3.2. Data

The air cargo data collection for this research was carried out over one year, where data from different sources between 2018 and 2022 were collected. First, aircraft data was sourced from Airfleets[4] and PlaneSpotter[5]. Both sources provide information about aircraft movements between operators and provide an overview of the status of airframes for all airlines worldwide. The registration plate data for all wide-body and narrow-body freighter aircraft between 2018 and 2022 were collected. This way, the actual and historical registration plates for the aircraft were included. The collected wide-body registration plate data was used as input on flight tracking websites to collect flight data. Three flight tracking websites were considered: Flightera[6], Flightradar24[7] and FlightAware[8]. All have published flight data on flight date, origin, destination, actual departure time, arrival time and flight duration for each registration plate. Flightera and Flightradar24 also provide data on the flight number. Data from Flightera is freely available for December 2017 onwards and was collected from January 2018 until February 2022. Flightradar24 data was collected from October 2019 to December 2022. FlightAware data was collected from October 2021 until December 2022. Due to resource constraints, mainly time constraints as collecting such an amount of data can be rather time intensive, the narrow-body freighter data was only collected from FlightAware and Flightradar24 for 2022. All the collected data were combined. Combining heterogeneous datasets can be a rather tedious task as it might cause challenges and problems. Next to differences in features published or missing data, dealing with near duplicates due to time zone differences or time deviations were also major challenges. Those four challenges were solved as follows:

1. When comparing and integrating those sources, the first challenge tackled was the mismatch of features between the different flight tracking websites. All sources published data on the day, month and year of the flight, the origin and destination, and the departing and arriving times. Due to the scope of this research, those features were sufficient, and all the others were removed. Although those features are sufficient for the purpose of this research, flight code or scheduled departure and arrival times might be interesting for future research. The flight codes can be interesting in identifying the code-sharing behaviour of airlines, analyses of individual airline networks or calculation of market shares on certain routes and networks. Scheduled departure and arrival times can be interesting for airport analyses, airline punctuality, or for research towards airport optimisation models.

2. The time-zone problem was solved by converting all times to the Coordinated Universal Time (UTC).

3. The small mismatches in timings were partly solved by counting the flights with the same data, origin, destination, and registration plate per source. First, if there were no duplicates, we assumed that there was only one flight with that specific aircraft between the origin and destination on that day. The results for all three sources were compared, and the timings were considered if the flight had no duplicates in all sources. If the differences between the UTC timings between all three sources were less than 15 minutes, we assumed those flights to be duplicates. The decision must be taken manually if the difference was higher than 15 minutes, which was rarely the case. Second, if duplicates were found or some sources found a duplicate while the others did not, time brackets of one hour were used, meaning that each timing was rounded to the closed hour. Afterwards, the process was repeated, including the new time brackets.

[4]https://www.airfleets.net/home/
[5]https://www.planespotters.net/production-list/index
[6]https://www.flightera.net/en/
[7]https://www.flightradar24.com/
[8]https://flightaware.com/

If there were still problems, those cases also needed to be checked manually. We are aware that this probably does not solve all mismatched timing and that one of the two can be rounded off to the previous hour while the other can be rounded off to the next hour. Although we acknowledge that our methods of dealing with mismatches in timings are not perfect, we believe the overall impact to be limited.

4. Regarding the missing data features, the main missing features were origin or destination related. As filling in the missing data was impossible, those rows were removed.

Afterwards, we compared the Available Cargo Tonnes (ACT) of 2021 with a correction of the narrow body freighter capacity of 2022, as we do not have them for 2021, of our comprehensive database with the ACT numbers published by IATA in its quarterly chartbooks (2015-2023). We found our ACT data to be 6.3% above that of IATA. Although the 6.3% may indicate that not all duplicates were removed, we believe the maximum payload for each aircraft used can explain the difference. Because the maximum payload is seldom reached, our data is subject to overcalculation which might explain the 6.3%. Because we are aware that our methods are not perfect, we believe more research is required on the integration of different sources, the payloads used, and the comparison of our dataset with more data sources to validate our methods.

Combining those three sources allows for a more comprehensive database. The combined database is then compared to the three sources individually to assess the accuracy of each source. Flightradar24 was the most comprehensive source covering 91% of the combined database. FlightAware covers 88%, and Flightera 83%. As Flightera is our prime source for January 2018 until September 2019, a deeper dive into the data was conducted to understand better which data is missing leading to an 83% accuracy. As it turns out, wide-body passenger aircraft flights have an accuracy of 96%, even higher than the Flightradar24 data. The problem is with the full freighter data. By analysing the freighter data on a daily level, a steep decline of 50% of data is found in July 2019. Extra freighter data from May 2019 until September 2019 was collected from Flightradar24 to determine if the decline is due to data issues or sudden events in the market. As the Flightradar24 data does not show any decline, we concluded that the Flightera data has a gap in freighter data from July 2019 onwards. This gap was filled by including the extra Flightradar24 data. The combined database was cleaned by combining the origin and destination IATA codes with their respective countries, regions, and coordinates. The regions are defined as shown in Figure 1; North America (NA), Central America (CA), South America (SA), Europe (EU), Africa (AF), Middle East (ME), Russia and Central Asia (RU), Northeast Asia (NEA), Southeast Asia (SEA), China (CH), and Indian Sub- Continent (INS). The available maximal payload was applied for each flight based on the cargo tonnes for different aircraft types defined by Bombelli et al. (2020). For the missing aircraft types, the A350-900, the A350-1000 and the B787-10, a payload of respectively 17 tonnes, 25 tonnes, and 13 tonnes was applied (IAG, 2023). Each flight was given an identifier to allocate capacity to wide-body, freighter or integrator aircraft.

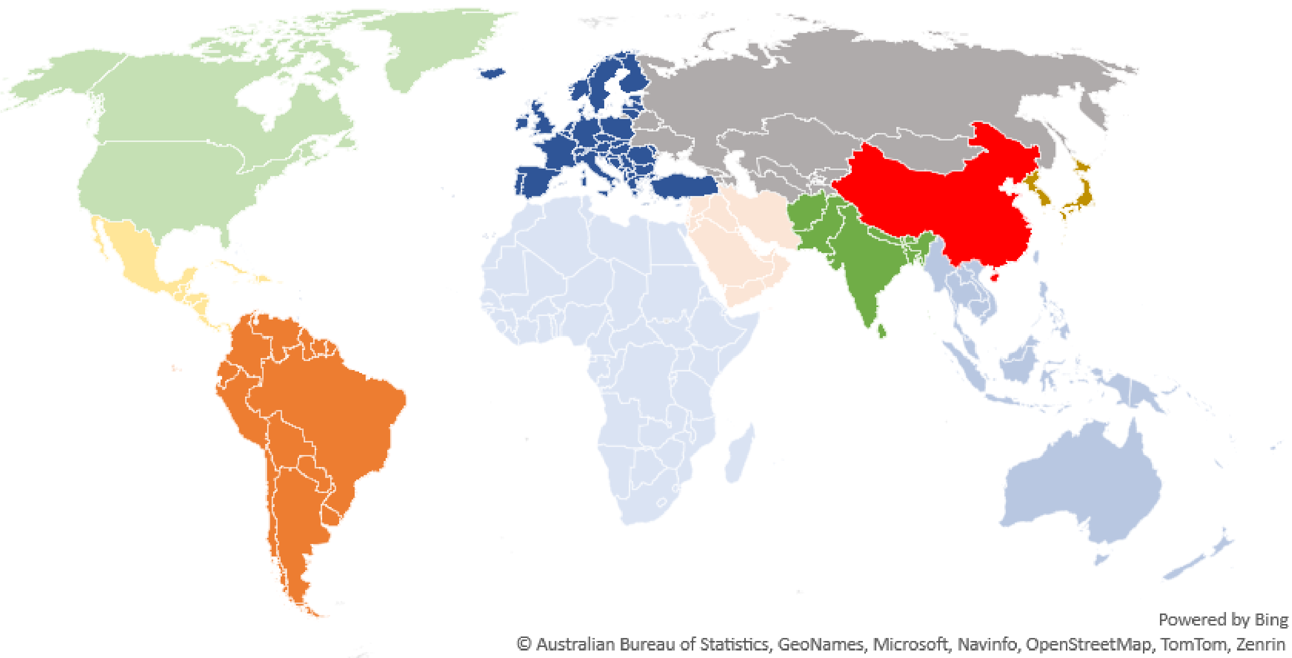

Figure 1: *Region definition.*

The demand data originates from the World Air Cargo Database (World_ACD). The World_ACD collects and combines Air waybill (AWB) data to build a comprehensive air cargo market database. This database provides sales tonnes, expressed in both chargeable and actual weights, data from an origin airport or city to its final airport or city. The sales tonnes data includes charters-on-AWB data and mail-on-AWB data but excludes express flown by integrators and charter and mail data not sold on AWBs. Chargeable weight can be defined as the measurement used by cargo carriers to determine the price for the shipment of your goods. It can either be the gross weight or the shipment's volumetric weight (Chao and Li, 2017). The data is provided for the period 2018 until 2022 and is provided on a country-to-country level. The country-to-country data are transferred to region-to-region data based on previously defined regions. The data also includes trucking on AWB data, but we believe the impact will be limited due to the aggregation of the data to regional levels. Next to the World_ACD data, demand and supply data was collected from IATA's quarterly published air cargo chartbook as well as from IATA's monthly published air cargo analysis. Next to IATA, data are also sources from Boeings' world air cargo forecast published bi-annually and from ICAO's annual report of the council.

4. Aggregated global market analysis

This section will discuss air cargo demand and supply based on aggregated global market data. Different types of air cargo demand data sources are compared and discussed. Afterwards, the role and impact of double counting due to transfer data are explained. Regarding the air cargo demand, the air cargo capacity is estimated and allocated to wide-body belly capacity, freighter capacity, and integrator capacity. Finally, both air cargo demand and supply are compared and air cargo rates are included.

4.1. Air cargo demand

Air cargo demand data are the most readily available. The most common unit of measurement of air cargo demand is the Freight Tonne Kilometre (FTK), representing the transport of one tonne of freight over one kilometre. Multiple international organisations publish air cargo demand data expressed in FTK. Figure 2 shows the FTK data IATA, ICAO, the World Bank, and Boeing[9] provided from 2001 until 2020. As Figure 2 illustrates, reported FTK data from different sources shows discrepancies. Those discrepancies are common, as each organisation has its methodology for collecting and defining FTK.

For 2003-2017, IATA and ICAO data are relatively similar. The similarity is not a coincidence, as both sources publish scheduled FTK data. Although both sources publish the same kind of FTK data, since 2018, the IATA data has suddenly increased compared to the ICAO data. In the last few years, IATA started using Cargo Tonne Kilometres (CTK) rather than FTK as their main reporting unit for air cargo demand. CTK data included freight, mail, and unaccompanied baggage. Although the data for those years was reported in FTK, we assume it is probably CTK data as it matches other CTK data published by IATA. Unfortunately, no confirmation by IATA could be found. The FTK data published by Boeing are higher than IATA's or ICAO's figures. The difference can be found in charter data, as Boeing issued actual rather than scheduled data. The World Bank data, a source often used for forecasting air cargo demand, is based on ICAO data. For most of the years, it follows the same trends as the ICAO data, except in 2009, where it increased while all the other sources show decreasing demand due to the financial crisis. Regarding data usage and comparison from institutions, one must take into account which data is included or excluded.

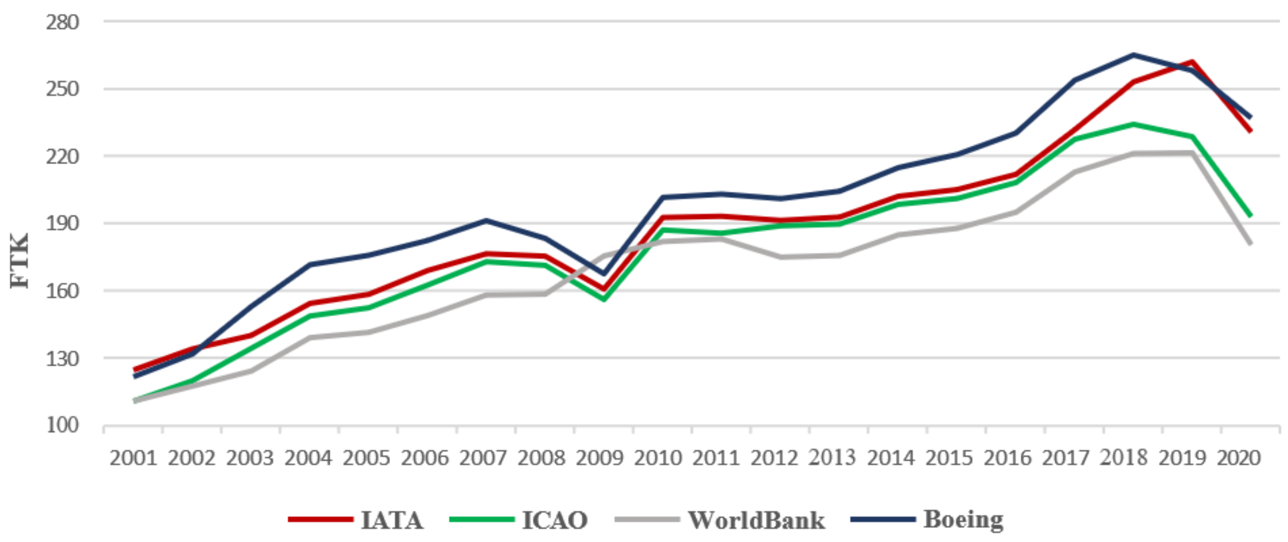

Figure 2: *Industry's freight tonne kilometre evolution.*

[9]The data provided by Boeing was expressed in Revenue Tonne Kilometre (RTK). In general, RTK includes the total number of passengers and cargo tonnes. Boeing defines RTK as a performance metric; one tonne of revenue freight carried one kilometre. Usually interchangeable with FTK but may include passenger and luggage weights for total revenue. Boeings RTK data is very similar to other FTK data but differs from RTK data provided by other sources.

Figure 3 illustrates the global evolution of actual cargo tonne-kilometres performed by the industry. The growth of air cargo is similar to the growth of air freight, with a drawback in 2008 and 2009 due to the financial crisis and in 2020 due to the COVID-19 Pandemic. The first drawback can also be found for international express cargo, as the financial crisis impacted the purchasing power of the customers. Compared to the second drawback of freight in 2020, express boomed by 8.1% compared to 2019. This increase can be explained due to people spending more money on online shopping as they needed less money for social activities and travelling due to lockdowns. International express cargo is the quickest-growing air cargo segment growing from an international market share of 13.4% in 2008 to 21% in 2021. Compared to the ever-increasing express segment, the air mail segment steadily decreased from a market share of 5.2% in 2001 to 1.8% in 2021. Although the market share of air mail has been declining slowly over the last 20 years, the COVID-19 pandemic accelerates this decrease. Although the air cargo charter market is a small part of the general market, with a market share of around 6.9% before COVID-19, the COVID-19 pandemic caused the charter market share to almost triple to 17.3% in 2021. Most charter data is often neglected in analysing the market due to the use of scheduled data; this increase must be addressed when observing data from 2020 onwards. Therefore, working with actual flown data rather than scheduled data is essential.

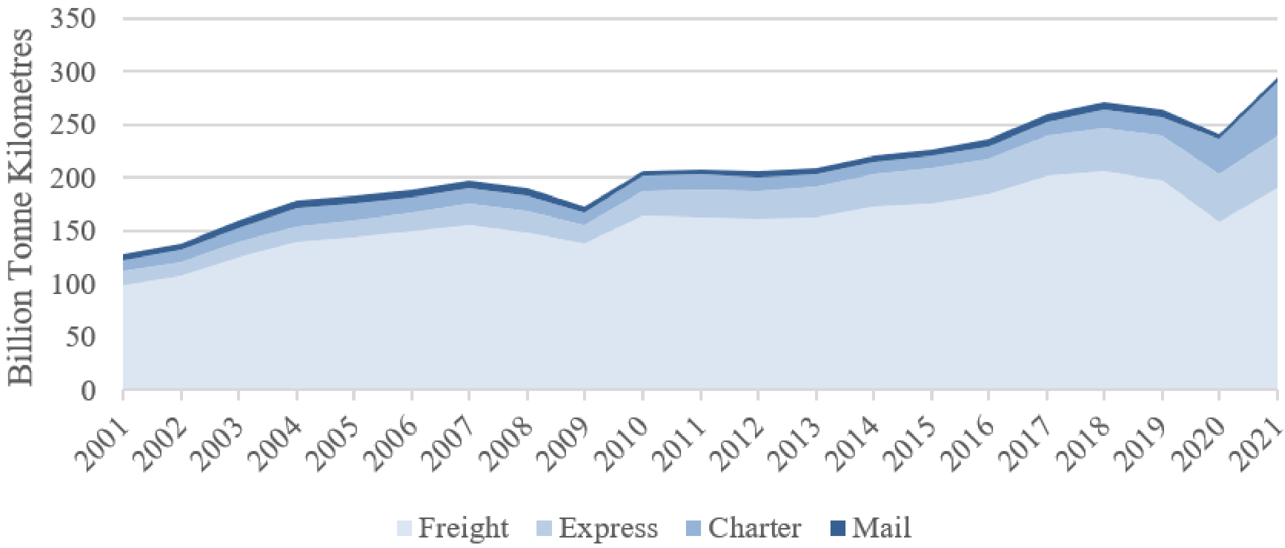

Figure 3: *Industry's freight, express, charter and mail-tonne kilometre evolution.*

Next to FTK and CTK, another unit of measurement for air cargo demand often used is carried tonnes. Carried tonnes express the actual weight of all cargo transported. Figure 4 illustrates domestic and international cargo tonnes carried from 1998 until 2021. In the first ten years, domestic and international traffic experienced an average growth of 4.37% per year. From the financial crisis in 2008 onwards, international cargo traffic, with an average annual growth of 4.75%, outperformed the 2.42% average annual growth rate of domestic traffic.

From a financial point of view, another unit of measuring air cargo is sales tonnes. Sales tonnes are the air cargo sold at a specific price and transported from an origin to a final destination airport or city as provided on the air waybill (AWB). Sales tonnes data exclude transfers, thus excluding double counting, and are at the bases for calculating revenue as air cargo rates are multiplied by them. Figure 4 illustrates the international carried tonnes to be higher than the international sales tonnes indicating much double counting into the industry. Due to the missing express data of integrators in the World ACD data, the international carried tonnes cannot be divided by the sales tonnes to estimate how much double counting there is in the industry.

4.2. Air cargo supply

Unlike air cargo demand, previously discussed institutions rarely publish data on the air cargo supply side. IATA publishes air cargo supply data in its annual World Air Cargo Statistics (WATS). The data is expressed in Available Cargo Tonne Kilometres (ACTK) by reporting airline and is divided into international and domestic ACTK, and scheduled, charter and all cargo operations. ACTK is compared towards CTK to determine the weight load factor. Another way of measuring air cargo supply is by calculating the Available Cargo Tonnes (ACT). ACT considers the available capacity of a flight regardless of the distance of this flight. Due to the scope of this research, the ACT capacity is preferred as the focus is on weight parameters rather than weight-kilometre parameters.

One problem with ACT data is the need for more publicly available data. To solve this problem, data from flight traffic websites were collected and processed to build a comprehensive database. The methodology can be found in section 3.2. Figure 5 illustrates the ACT on an international level, divided into wide-body belly capacity, dedicated freighter capacity,

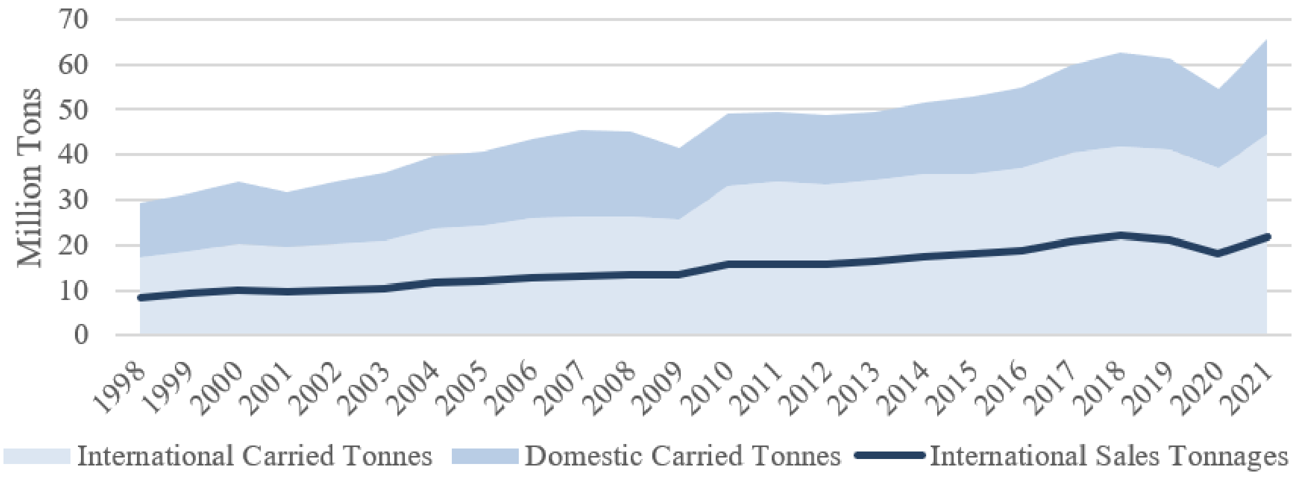

Figure 4: *International versus Domestic carried Tonnes and International Sales Tonnes.*

and integrator capacity. The data reveal that in 2019 around 59% of the capacity can be allocated to wide-body belly capacity on international traffic. This allocation is higher compared to the 50% market share on an industry level published by Boeing. This would indicate that freighter and integrator capacity have a higher domestic market share than international levels. Indeed, when domestic data is included in the equation, the 59% wide-body capacity decreases to a market share of 51%, relatively close to the market share published by Boeing. The reason for the lower market share for wide-body on an international level compared to a domestic level is twofold. First, the data show that in 2019 54% of integrator data was dedicated to domestic flights increasing the overall freighter capacity on the domestic markets. Second, Anchorage is one of the world's largest airports for in-transit flights, connecting Asia with North America. Because Anchorage is part of the United States, many freighter flights connecting Anchorage with other United States airports are counted as domestic flights.

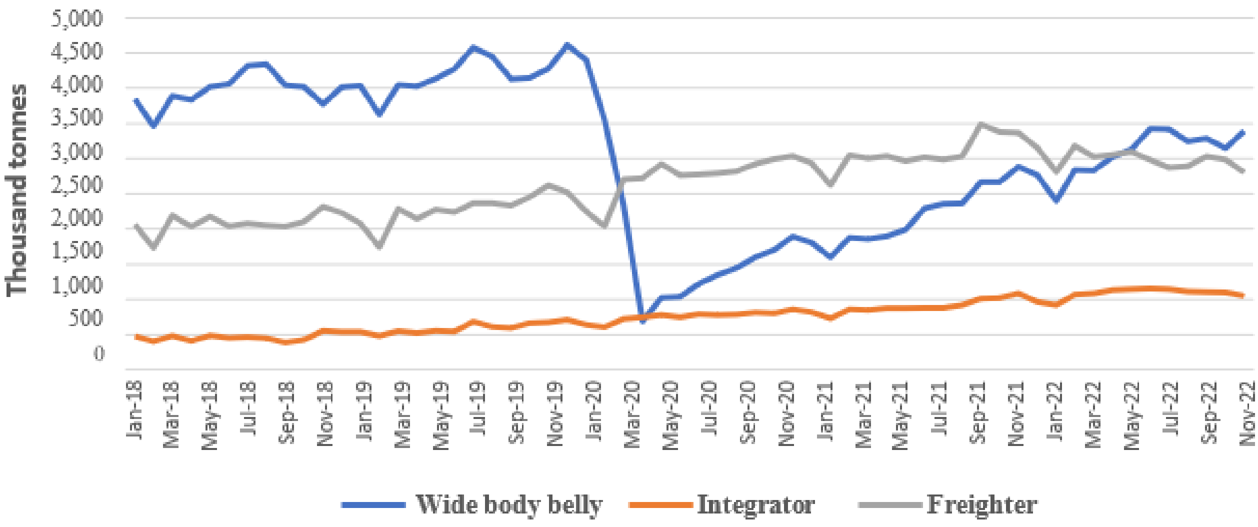

Figure 5: *International available cargo tonne evolution for belly, integrator and freight capacity.*

Figure 5 illustrates the impact of the COVID-19 pandemic on the air cargo market. Due to the travel restrictions, wide-body belly capacity plummeted to around 700,000 ACT in April 2020. Since 2021, wide-body passenger capacity started its slow recovery process. In December 2022, the international wide-body belly capacity is still 36% under 2019 levels. Freighter capacity and, to a lesser extent, integrator capacity started increasing after March 2020 to substitute the declining wide-body belly capacity. In 2022, freighter and integrator capacity accounted for 57% of international ACT. Although the current methodology provides us with some interesting data, it has three main areas for improvement. First, the narrow-body freighter and narrow-body passenger aircraft should be included in Figure 5. Although narrow-body aircraft generally operate on domestic routes in larger countries like the United States or Australia, in Europe and certain parts of Asia, narrow-body aircraft operate cross-border flights. Second, preighter aircraft data is currently included as wide-body belly capacity. Although preighter flights did not occur in 2018 and 2019, IATA and Boeing's data show a 10% market share of preighter aircraft in 2020, with peaks up to a market share of 25% in May 2020. As of 2022, preighter flights accounted for a market share of 5%. Last, the aircraft payload data used in the current methodology is based on maximum payload figures. The maximum payload is seldom reached as multiple factors, like flight distance, airport elevation, jet stream, etc., can influence the payload. Using a maximum payload, the data and results are subject to overestimation. Indeed, when dividing the international cargo tonnes carried by the international available cargo tonnes for the 2019 data, a load factor of 48.8% was found. This load factor is lower than the 50.4% indicated by IATA, indicating an overestimation of the international ACT as demand data for both calculations is the same.

4.3. Combining Demand and supply on an international level

The above two components, demand and supply, were discussed separately. Figure 6 shows those components combined with air cargo rates provided by the World_ACD from January 2018 until December 2022. Both demand and supply are expressed in cargo tonnes, including double counting due to transfers, while the air cargo rates are expressed in a price per kilogram chargeable weight. In 2019, the international air cargo demand decreased by around 5% compared to 2018. Due to the air passenger growth in the first two years, wide- body belly capacity increased. Next to the wide-body belly capacity, the freighter and integrator capacity also expanded on the international market. Despite the decrease in air cargo demand, the increase of freighters and integrators on an international level can be explained due to the decline in domestic demand, making international routes more profitable than domestic routes. The same happened in the following years, where the freighter and integrator share on the international routes increased while it decreased on the domestic routes. The increased supply and decreased demand caused air cargo rates to decline on an international level between January 2018 and December 2019. Since the outbreak of the COVID-19 Pandemic, air cargo supply has plummeted due to the grounding of wide-body belly capacity.

Over the last three years, the air cargo supply almost recovered to pre-COVID-19 levels. As Figure 5 illustrates, supply recovery is more due to additional freighter and integrator capacity in the market than the wide-body belly capacity recovery. Although the COVID-19 pandemic impacted air cargo demand, the impact was relatively small, and the demand recovered quickly, reaching a record-breaking year in 2021. The Ukraine-Russian war and the subsequent economic recession caused air cargo demand to decrease in 2022. After air cargo rates almost tripled in April 2020, they declined to double the pre-COVID-19 rate around the summer of 2020 nearly. Between the summer of 2020 and 2021, air cargo rates stabilised as demand and supply increased. In the last three months of 2021, air cargo rates increased from around $3.2 per kilogram to around $4.4 per kilogram. As air cargo supply increased significantly more than air cargo demand, air cargo rates were expected to decrease. The reason they grew rather than fell can be found in the supply chain issues on the pacific trade lines, where demand increased, and supply could not keep up. This problem resulted in rates of above $15 per kilogram on some routes. Because of the significant size of those trade lines, the exceptionally high rates can also be found in the international air cargo rate data, which is a weighted average of the individual market trade lines. Since the start of 2022, air cargo rates have decreased to around $3.2 per kilogram at the end of 2022.

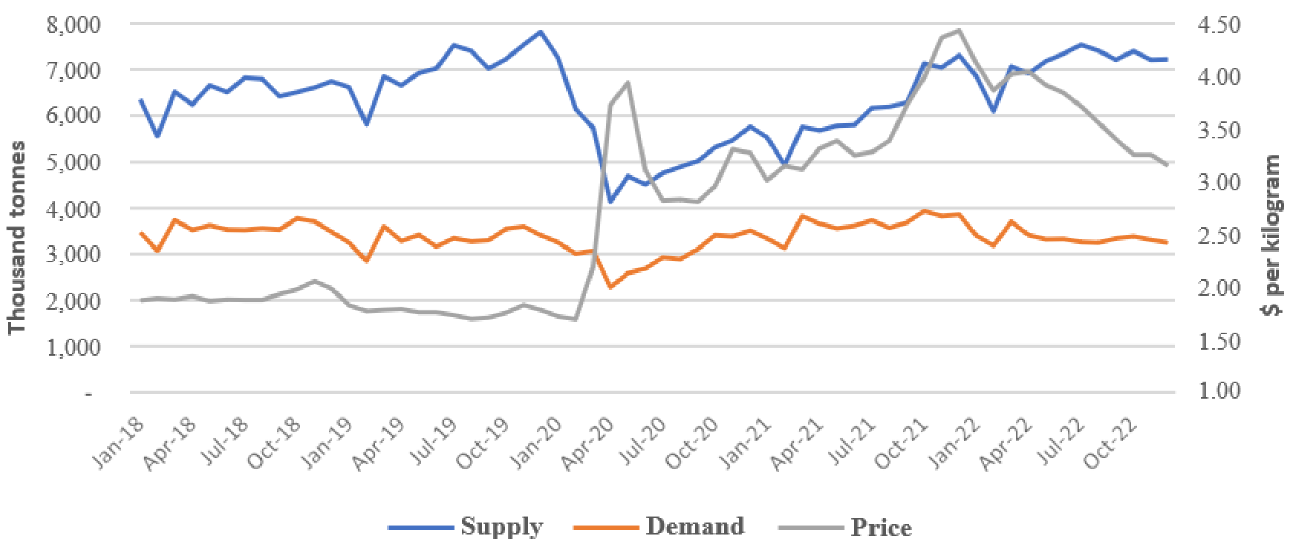

Figure 6: *An air cargo supply, demand and price evolution from January 2018 until December 2022.*

5. Disaggregated main trade line market analysis

This section will discuss air cargo market imbalances between eleven pre-defined regions. The imbalances are both estimated and discussed for the demand and supply sides. The demand imbalances are estimated based on sales tonnes rather than actually carried tonnes. This way, transfer and in-transit data are excluded revealing the actual origins and final destinations of air cargo flows. The supply imbalances are estimated for the three types of supply: wide-body belly, freighter, and integrator capacity. Afterwards, both the demand and supply imbalances are compared.

5.1. Air cargo demand imbalances on a region-to-region level

Regarding air cargo demand imbalances, Boeing provides carried tonnes data between regions in their bi-annual world air cargo forecasts. IATA provides CTK data in its IATA WATS or its online published reports. Both data types have been discussed by the institutions (Boeing, 2022) and in the literature (Morrell and Klein, 2019). Air cargo sales tonnes between regions have yet to be analysed and discussed. The benefit of studying air cargo sales tonnes is that it does not include double counting due to transfers. It shows the first origin of the cargo and its final destination. By excluding double counting, one can better analyse whether a region is an importing, exporting or balanced air cargo region. Double counting may blur the image and hides the actual cargo flows. For example, as Figure 7 indicates, 78,000 tonnes of air cargo originating in China and finding their final destination in South America were sold in 2022. This 78,000 tonnes of cargo is enough to fill 780 B777F flights with maximum payload, indicating the significance of this route. When looking at actual carried tonnes, traffic between China and South America is not found as the flight distance is too far.

Figure 7 provides a matrix of the eleven defined regions and the sales tonnes of cargo sold in 2022 between those regions; the importance of the Northern Hemisphere trade lines can be seen. The most extensive air cargo trade lines are between Europe and North America, followed by China to Europe and China to North America. The fifth biggest trade line, South America to North America, may be surprising. This trade line is characterised by perishable cargo, mainly fruit and vegetables. Europe is the leading exporting region, with an export of 4.56 million tonnes of export cargo. North America is the most extensive importing region, with 4.10 million tonnes of imported cargo. China is a typical export market as its export is more than double its import. China is a production country importing raw materials by sea trade and exporting intermediate or finished products. On the other side, the Middle East can be considered an importing region with an import of 1.47 million tonnes compared to its export of 0.39 million tonnes.

O\D	NA	EU	CH	SEA	NEA	INS	ME	AF	RU	CA	SA	Export
NA	-----	941	225	398	274	78	159	45	22	125	343	2,610
EU	1368	-----	566	574	366	259	618	311	91	164	238	4,555
CH	842	987	-----	560	227	197	229	127	27	69	78	3,343
SEA	537	384	482	-----	250	66	72	17	8	9	9	1,833
NEA	219	210	235	299	-----	33	19	10	5	5	9	1,044
INS	174	404	49	68	28	-----	165	51	10	8	15	973
ME	63	125	12	22	6	47	-----	90	12	2	5	385
AF	37	438	15	17	6	6	175	-----	5	1	1	702
RU	3	7	4	5	1	2	7	1	-----	0	0	30
CA	149	100	15	7	10	4	12	2	1	-----	22	321
SA	709	298	29	13	17	5	18	7	3	42	-----	1,141
Import	4,102	3,894	1,631	1,964	1,186	698	1,474	660	185	426	719	16939

Figure 7: *Overview of sales tonnes transported between the studied regions in 2022 (thousand tons).*

Regarding trade imbalances, Figure 8 gives an overview of the imbalances in absolute terms between the different regions. Around half of the trade lines are imbalanced markets with an imbalance larger than 50,000 tonnes. The region pair with the most significant imbalance is the China - North America route, with an imbalance of 617,000 tonnes. China's export to North America is 617,000 tonnes higher than its import from North America. Other highly imbalanced routes are Europe – North America, Europe – Middle East, China – Europe, and South America – North America Routes. The total imbalance between export and import does not have to be the same for all its exporting and importing regions. Europe, for example, has a positive trade weight balance with North America, meaning that Europe's air export volumes to North America are higher than its import volumes. While Europe has a positive trade weight balance with the Middle East, Southeast Asia, and Northeast Asia, it has a negative trade weight balance with China, the Indian Sub-Continent, and Africa. Another region with both positive and negative trade weight balances is the Indian Sub-Continent which has a positive trade weight imbalance with Europe, North America, and the Middle East but a negative trade imbalance with China. Generally, most regions are characterised by either a negative or a positive trade weight imbalance. For example, China has a positive trade imbalance for almost all its routes, while the Middle East and North America have a negative trade imbalance.

O\D	NA	EU	CH	SEA	NEA	INS	ME	AF	RU	CA	SA
NA	-----	-427	-617	-139	55	-96	96	8	19	-24	-366
EU	427	-----	-421	190	156	-145	493	-127	85	64	-60
CH	617	421	-----	78	-8	148	217	112	23	54	50
SEA	139	-190	-78	-----	-49	-2	50	-1	3	2	-4
NEA	-55	-156	8	49	-----	5	13	4	4	-6	-8
INS	96	145	-148	2	-5	-----	118	45	8	4	9
ME	-96	-493	-217	-50	-13	-118	-----	-85	5	-10	-13
AF	-8	127	-112	1	-4	-45	85	-----	4	0	-6
RU	-19	-85	-23	-3	-4	-8	-5	-4	-----	0	-3
CA	24	-64	-54	-2	6	-4	10	0	0	-----	-20
SA	366	60	-50	4	8	-9	13	6	3	20	-----

Figure 8: *Overview of the sales tonnes imbalances between the studied regions in 2022 (thousand tons).*

5.2. Air cargo supply imbalances on a region-to-region level

5.2.1. Air cargo supply imbalances for the freighter network

Air cargo supply imbalances have been studied by Bombelli et al. (2020), who analysed the air cargo supply network. They mainly focused on origin-destination pairs on an airport-to-airport level. The main contribution of the next section will be the allocation between freighter, integrators and wide-body belly capacity, and on the region-to-region rather than the airport-to-airport approach. The data used in this section is from 2022 and was collected from flight tracking websites. It includes both wide-body passenger and freighter aircraft and narrow- body freighter aircraft. Further information on the methodology can be found in Section 3.

The freighter network is the most imbalanced one of the three studied types. Figure 9 gives an overview of the ACT between the studied regions. Compared to the air cargo demand, air cargo supply inbound has to be equal or almost equal to outbound. This is not the case for air cargo demand, as the load factor of the aircraft is different on different trade lines. As Figure 9 indicates, there is some variation between the inbound and outbound capacity of the same region. The data assumes the maximum payload of each aircraft type without considering other factors like flight distance, weather conditions, airport elevation, etc., which can impact the payload. The reason for those imperfections can be found in the data of the flight tracking website themselves and the incompleteness of specific data points causing flights to be deleted in the cleaning process. Routes with a high freighter capacity are generally considered routes with a low wide-body belly capacity or a high air cargo demand. As for air cargo demand data, freighter aircraft data shows that air cargo is mainly a Northern Hemisphere business.

O\D	NA	EU	CH	SEA	NEA	INS	ME	AF	RU	CA	SA	Export
NA	-----	1418	455	628	1210	0	19	7	36	573	682	5,028
EU	1036	-----	621	354	589	140	1280	367	749	134	120	5,392
CH	809	557	-----	665	817	161	166	49	382	0	0	3,607
SEA	962	249	780	-----	846	419	804	62	247	11	0	4,380
NEA	939	241	1071	1207	-----	9	80	3	163	10	0	3,723
INS	0	223	137	293	10	-----	235	18	17	0	0	932
ME	3	1166	160	899	96	201	-----	168	66	0	0	2,759
AF	5	490	19	29	2	12	71	-----	15	2	87	731
RU	14	865	343	253	96	27	46	9	-----	2	0	1,655
CA	589	125	0	1	1	0	0	0	2	-----	127	845
SA	776	76	0	0	0	0	0	17	0	119	-----	987
Import	5,135	5,408	3,586	4,328	3,667	968	2,702	700	1,677	852	1,017	

Figure 9: *Overview of the freighter capacity between the studied regions in 2022 (thousand tons).*

Figure 10 illustrates the freighter imbalances between different regions. The biggest imbalances are between North America – Europe, Southeast Asia – North America, China – North America, Europe – Northeast Asia, and Northeast Asia – Southeast Asia. Those imbalances are generally between the main three air cargo regions; Europe, North America and Asia. As is not the case for air cargo demand, those imbalanced regions cancel each other out as inbound aircraft capacity should be the same as outbound capacity. Figure 11 illustrates the imbalances which are higher than 50,000 tonnes. Some potential triangular or multisector flight sectors can be found based on those imbalances. The main potential sectors are CN-NA-NEA-CN, NEA-RU-EU-NEA, EU-ME-AF-EU, EU-ME-AF-SA-NA-EU, SEA-INS- EU-SEA, and EU-CN-NA-EU as can be seen on Figure7. In-depth database analysis is needed to identify the actual sectors' flow and how often they are operated.

O\D	NA	EU	CH	SEA	NEA	INS	ME	AF	RU	CA	SA
NA	-----	381	-354	-335	271	0	16	2	22	-16	-94
EU	-381	-----	65	106	348	-83	115	-122	-116	9	45
CH	354	-65	-----	-115	-254	24	6	30	39	0	0
SEA	335	-106	115	-----	-361	126	-95	34	-6	11	0
NEA	-271	-348	254	361	-----	-1	-16	1	67	9	0
INS	0	83	-24	-126	1	-----	34	6	-10	0	0
ME	-16	-115	-6	95	16	-34	-----	97	20	0	0
AF	-2	122	-30	-34	-1	-6	-97	-----	7	2	71
RU	-22	116	-39	6	-67	10	-20	-7	-----	0	0
CA	16	-9	0	-11	-9	0	0	-2	0	-----	8
SA	94	-45	0	0	0	0	0	-71	0	-8	-----

Figure 10: *Overview of the freighter capacity imbalances between the studied regions in 2022 (thousand tons).*

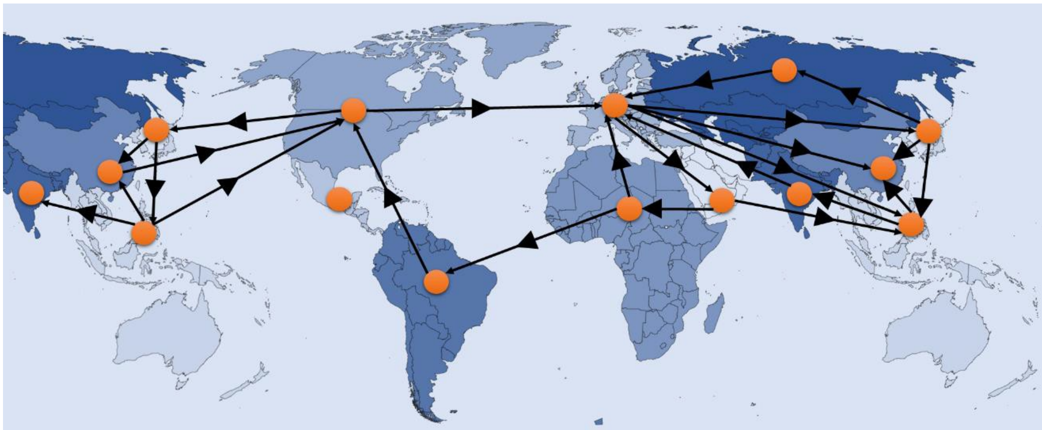

Figure 11: *Overview of the top 20 most imbalanced routes based on freighter capacity in 2022.*

5.2.2. Air cargo supply imbalances for the integrator network

The integrator capacity is generally less imbalanced than the freighter capacity but more imbalanced than the wide-body belly capacity. Integrator traffic is even more northern hemisphere focused than its freighter counterpart. When observing Figure 12, one might notice a 100,000 tonnes imbalance between Southeast Asia's outbound and inbound capacity. Although general gaps are explained due to cleaning, data provision, and processing errors, a 100,000 gap on an average-size route is exceptional. A more in-depth database analysis is required to understand better what type of error causes a gap of around 7.5% in the data.

When it comes to imbalances, Figure 12 indicates an unusual imbalance between North America and the Middle East. No records were found for flights from the Middle East to North America. This is unsurprising as the Middle East is generally an import region, importing high- end products from developed regions like North America. The same imbalance can be found between Southeast Asia and the Middle East and between the Indian Sub-Continent and the Middle East. From the Middle East, the excess capacity flies to Europe to be redistributed to North America or Southeast Asia. Another significant imbalance exists between North America and China/Southeast Asia. This imbalance also occurred on the freighter network. At the same time, the imbalance between North America and Northeast Asia is more minor but also in the other direction, from North America to Northeast Asia.

O\D	NA	EU	CH	SEA	NEA	INS	ME	AF	RU	CA	SA	Export
NA	-----	705	130	255	661	0	93	3	0	451	125	2,423
EU	762	-----	62	151	99	72	236	37	7	0	0	1,426
CH	199	38	-----	292	587	45	48	0	0	0	0	1,209
SEA	321	68	346	-----	422	81	152	3	2	0	0	1,395
NEA	637	76	607	463	-----	0	27	3	1	0	0	1,814
INS	0	105	42	11	0	-----	142	0	0	0	0	300
ME	0	386	61	118	27	90	-----	33	0	0	0	715
AF	4	35	0	0	1	0	42	-----	0	0	0	82
RU	0	4	0	5	1	0	0	0	-----	0	0	10
CA	453	0	0	0	0	0	0	0	0	-----	44	497
SA	136	0	0	0	0	0	0	0	0	44	-----	180
Import	2,512	1,417	1,248	1,295	1,798	288	740	79	10	495	169	

Figure 12: *Overview of the integrator capacity between the studied regions in 2022 (thousand tons).*

5.2.3. Air cargo supply imbalances for the wide-body belly network

The air cargo wide-body belly capacity is generally balanced between the trade lines. Although aircraft generally operate both legs of an origin-destination pair, this is not always the case. Sometimes airlines perform one leg with an A350-900 aircraft and the other with a B777- 300ER. Both aircraft have another air cargo belly-hold payload causing inconsistencies in the data. The reason airlines often switch aircraft on both legs of the same route can be twofold. First, on a long-haul flight, due to the jet stream, the flight time on one leg can be up to two hours longer than the flight time on the other leg. The two-hour longer flight leg requires a higher payload for fuel resulting in a lower payload for cargo in the belly hold. Airlines can optimise their air cargo operations by using more cargo-friendly or more efficient aircraft on highly cargo-imbalanced routes. Due to the imperfection and data aggregation, it is unclear on which routes and how often those switches happen. Further research into the database is needed to analyse how often a different aircraft is used on one leg compared to the return leg. Also, more research on the reason behind those switches is needed. Although it is difficult to say which routes are imbalanced due to those aircraft switches, two region-to-region combinations stand out. First, the Europe to Southeast Asia route has an ACT of 549,000 tonnes, while the Southeast Asia to Europe route has a payload of 628,000 tonnes. Second, the Europe to Africa route has a payload of 776,000 tonnes compared to the 866,000 tonnes on Africa to Europe route.

O\D	NA	EU	CH	SEA	NEA	INS	ME	AF	RU	CA	SA	Export
NA	-----	3131	101	493	591	99	451	131	6	110	344	5,456
EU	3077	-----	215	549	211	322	1390	776	187	609	591	7,927
CH	104	218	-----	447	196	12	57	36	31	0	0	1,099
SEA	481	628	446	-----	961	224	668	29	20	0	4	3,460
NEA	589	210	186	814	-----	28	62	31	20	7	0	1,919
INS	109	324	9	263	28	-----	1027	32	20	0	0	1,811
ME	439	1386	54	657	58	1022	-----	642	71	0	27	4,357
AF	109	866	31	30	31	31	661	-----	31	1	16	1,807
RU	6	185	30	21	20	20	72	29	-----	15	1	400
CA	112	609	0	0	7	0	0	1	15	-----	55	799
SA	347	557	0	4	0	0	27	14	1	64	-----	1,014
Import	5,373	8,114	1,074	3,278	2,104	1,758	4,415	1,692	401	807	1,038	

Figure 13: *Overview of the wide-body belly capacity between the studied regions in 2022 (thousand tons).*

5.3. Comparison of air cargo supply and demand imbalances

As discussed above, both air cargo demand and supply are imbalanced between regions. Comparing sales tonnes demand imbalances with available cargo tonnes imbalances is useful for two reasons. First, while a region's total inbound and outbound are not equal for air cargo demand, they should be similar for air cargo supply. Aircraft entering a region either keep flying in the region or leave the region, meaning that their inbound and outbound capacity should be equal considering the usage of the aircraft's maximum cargo payload. The difference between inbound and outbound may cause disparities in the market. Second, by observing the sales tonnes rather than the carried tonnes, transfer data and double counting are excluded from the comparison. By excluding the transfer data, it is possible to get an indication of the transfer and in-transit region on a global market. Although the comparison may give a valuable indication, more research is needed on integrator express data as it is excluded from the demand side but included in the supply side. Currently, there is no publicly available information on how much cargo and express integrators carry and between which markets. Furthermore, more in-depth research is needed to estimate how many transfers are taking place and where they are happening. This requires a significant amount of detailed data, which is, to our best knowledge, yet to become available for academic research. Based on the sales tonnes data we received and the capacity database we built, we derived which regions are transfer or in transit regions. However, it will be challenging due to the above-described reasons.

Figure 14 compares the total sales tonnes and total available capacity between regions for 2022. Based on this comparison, some interesting aspects can be found. First, the Russian and Central Asia region has low import and export tonnes but high ACT. Transits can explain the high supply flows but low demand flows. Many airlines land at airports in Central Asian countries to refuel, as jet fuel is relatively cheap. The four main countries where aircraft might refuel are Azerbaijan, Kazakhstan, Kyrgyzstan and Uzbekistan. Those four countries accounted for 32% of the inbound originating from and outbound to Europe, East Asia and China in 2019. Those three regions are the three main regions flying to and from Central Asia. The 32% represents around 615,000 ACT and might seem small as it only accounts for one-third. The other country that accounts for 61% of traffic from and to those three regions is Russia. Although there is quite some capacity entering and leaving Russia, the Russian air cargo demand better matches this capacity. At the same time, this is not true for the four countries indicating their position as refueling hubs for cargo aircraft. Due to the Russian-Ukraine war, the role of those refueling hubs increased as certain European and Asian carriers could no longer enter Russian airspace. Indeed, when looking at the traffic, the data indicates a supply increase from 32% to 74% for those four countries or an increase from 615,000 ACT to 1,310,000 ACT. In comparison, the Russian share decreased from 61% to 21%, following the decrease in air cargo demand from and to Russia. By refueling, they can increase their air cargo payload, switch crew, and offer a broader range of farther destinations. Second, compared to its air cargo demand, the ACT of the Middle East and Northeast Asia are relatively high. This is not surprising as the Middle East is an air cargo and air passenger transfer region, and Northeast Asia is both a transfer and transit area for air cargo. While the Middle East connects Asia with Europe, Northeast Asia connects the other Asian regions with the United States. Another transit region is Central America, connecting South America with North America and Europe and Asia through North America. Conversely, the China and South American outbound routes seem congested. Based on those tables, both ways have the highest load factor of around 55% on average, indicating that those regions are unsuitable as transfer regions due to high demand and low supply.

Another observation indicates some region pairs to be partly or completely dependent on transfer or transit routes. Some clear examples of region pairs completely dependent are China to Central and South America and the other way around. Region pairs with direct capacity, but where the comparison indicate they are partly reliant on transfer or in transit flights are Indian Sub-Continent to North America, China to Europe and China to Africa. Those region combinations are not a surprise due to their long flight distances. Future research is required to look more in-depth at some region-to-region pairs, as region-to-region comparisons might be aggregated. For example, a lot of in-transit traffic happens in ANC, which currently needs to be shown in the region-to-region matrices.

O\D	NA	EU	CH	SEA	NEA	INS	ME	AF	RU	CA	SA
NA	-----	941	225	398	274	78	159	45	22	125	343
EU	1,368	-----	566	574	366	259	618	311	91	164	238
CH	842	987	-----	560	227	197	229	127	27	69	78
SEA	537	384	482	-----	250	66	72	17	8	9	9
NEA	219	210	235	299	-----	33	19	10	5	5	9
INS	174	404	49	68	28	-----	165	51	10	8	15
ME	63	125	12	22	6	47	-----	90	12	2	5
AF	37	438	15	17	6	6	175	-----	5	1	1
RU	3	7	4	5	1	2	7	1	-----	0	0
CA	149	100	15	7	10	4	12	2	1	-----	22
SA	709	298	29	13	17	5	18	7	3	42	-----

O\D	NA	EU	CH	SEA	NEA	INS	ME	AF	RU	CA	SA
NA	-----	5,254	686	1,376	2,462	99	563	141	42	1,134	1,151
EU	4,875	-----	898	1,054	899	534	2,906	1,180	943	743	711
CH	1,112	813	-----	1,404	1,600	218	271	85	413	0	0
SEA	1,764	945	1,572	-----	2,229	724	1,624	94	269	11	4
NEA	2,165	527	1,864	2,484	-----	37	169	37	184	17	0
INS	109	652	188	567	38	-----	1,404	50	37	0	0
ME	442	2,938	275	1,674	181	1,313	-----	843	137	0	27
AF	118	1,391	50	59	34	43	774	-----	46	3	103
RU	20	1,054	373	279	117	47	118	38	-----	17	1
CA	1,154	734	0	1	8	0	0	1	17	-----	226
SA	1,259	633	0	4	0	0	27	31	1	227	-----

Figure 14: *Comparison between sales tonnes (left) and total available capacity (right) between the studies regions for 2022 (thousand tons).*

Regarding region-to-region imbalances, some observations can also be made. Figure 15 gives an overview of both the sales tonnes imbalances and the ACT imbalances between regions for 2022; it indicates a significant demand imbalance between North America and Europe for both demand and supply. While the demand imbalance is negative for outbound of North America, the supply imbalance is positive. This indicates that although there is more demand from Europe to North America than from North America to Europe, there is lesser supply. This observation goes in against the general assumption that supply follows demand. Of course, this assumption still holds as the reason for this phenomenon is not due to airlines deliberately planning those mistakes, but it has rather to do with the significant demand imbalance North America has. A significant amount of supply is coming from Asia and Europe to North America. All this supply is left in North America and there is not enough demand due to the large demand imbalance to fly back. Many airlines are rather flying from Asia to North America to Europe and then back to Asia than flying from Asia to North America and back. This has a significant impact on the air cargo rates in the North America to Europe market, a market already dominated by wide-body capacity and negative trade imbalances.

Another region-to-region pair with the same problem but to a lesser extent is the China-to-Europe, China-to-Southeast Asia and to a lesser extent China-to-Middle East routes, where there is a positive demand imbalance for China's outbound, but a negative supply imbalance. China has a lot of outbound demand but significantly less inbound demand. Due to the equal inbound and outbound supply, airlines have to choose which routes they would rather serve and which routes they would fly empty or with a lower payload. In general, airlines choose to operate China-to-North America routes, which is a highly profitable route, rather than allocating their capacity to China to Europe, China to Southeast Asia and China to Northeast Asia routes.

O\D	NA	EU	CH	SEA	NEA	INS	ME	AF	RU	CA	SA
NA	-----	-427	-617	-139	55	-96	96	8	19	-24	-366
EU	427	-----	-421	190	156	-145	493	-127	84	64	-60
CH	617	421	-----	78	-8	148	217	112	23	54	49
SEA	139	-190	-78	-----	-49	-2	50	0	3	2	-4
NEA	-55	-156	8	49	-----	5	13	4	4	-5	-8
INS	96	145	-148	2	-5	-----	118	45	8	4	10
ME	-96	-493	-217	-50	-13	-118	-----	-85	5	-10	-13
AF	-8	127	-112	0	-4	-45	85	-----	4	-1	-6
RU	-19	-84	-23	-3	-4	-8	-5	-4	-----	-1	-3
CA	24	-64	-54	-2	5	-4	10	1	1	-----	-20
SA	366	60	-49	4	8	-10	13	6	3	20	-----

O\D	NA	EU	CH	SEA	NEA	INS	ME	AF	RU	CA	SA
NA	-----	379	-426	-418	297	-10	221	23	22	-20	-108
EU	-379	-----	85	109	372	-118	-32	-211	-111	9	78
CH	426	-85	-----	-168	-264	30	-4	35	40	0	0
SEA	388	-109	168	-----	-255	157	-50	35	-10	10	0
NEA	-297	-372	264	255	-----	-1	-12	3	67	9	0
INS	10	118	-30	-157	1	-----	91	7	-10	0	0
ME	-121	32	4	50	12	-91	-----	69	19	0	0
AF	-23	211	-35	-35	-3	-7	-69	-----	8	2	72
RU	-22	111	-40	10	-67	10	-19	-8	-----	0	0
CA	20	-9	0	-10	-9	0	0	-2	0	-----	-1
SA	108	-78	0	0	0	0	0	-72	0	1	-----

Figure 15: *Comparison between sales tonnes imbalances (left) and total available capacity imbalances (right) for the studied region in 2022 (thousand tons).*

6. Conclusions and limitations

One of the main shortcomings in air cargo market research is the lack of comprehensive data for academics. Although aggregated and, to a lesser extent, disaggregated data are published by large institutions, one needs to consider the methodology to find out what data is included or excluded as differences between datasets occur. Most market data publicly available is published by IATA, but also Boeing and ICAO publish data. The data is generally expressed in FTK, CTK, ACTK and RTK. All measures include both weight and distance. The available data is more limited regarding cargo tonne or available cargo tonne data and is often not comparable or different. This paper introduces two new types of air cargo market data. The first type is the sales tonnes. The sales tonnes are the tonnes sold from an origin to its final destination without double counting due to transfer data. This data type is especially interesting when observing country or region imports and exports as this data is generally hidden in the carried tonnes data. The second type is ACT data collected from flight tracking websites. A comprehensive database was built for five consecutive years, from January 2018 to December 2022. The data was collected from three different sources, which did not happen before.

Next to providing this new data, the data is used and tested in calculating air cargo market imbalances between eleven defined regions. Although air cargo demand and supply imbalances are not new and have been proven previously, the main contribution of this research is the usage of sales tonnes rather than actual tonnes as used by Boeing, a region-to-region complete market overview for the air cargo supply, and a comparison between directional demand and supply.

While large negative export imbalances were found for North America and the Middle East, a large positive export imbalance was found for China. All those regions, together with Russia and Central Asia, are dominated by either larger import or export air cargo volumes. For the remaining regions, the imbalances depend on the corresponding region. For air cargo supply, large imbalances were found for the freighter networks, limited imbalances for the wide-body belly capacity networks and medium imbalances for the integrator networks. Regarding the freighter network, large imbalances were found between the three main continents: North America, Europe, and Asia. By comparing air cargo demand and supply on a region-to-region level, it became clear that Northeast Asia, Russia and Central Asia, the Middle East, and Central America are all transfer or in-transit regions with a large amount of air cargo throughput. For the other regions, it is unclear whether they are transfer, in-transit or importing regions. Although the general assumption of air cargo supply following air cargo demand holds, it does not necessarily mean that the imbalances between demand and supply are the same for all region pairs. A good example can be found on the Europe – North America trade line where the demand imbalance is on the opposite leg than the air cargo supply imbalance. This phenomenon is explained by an excess air cargo supply, causing aircraft originating from Asia to fly back via the European mainland. Although comparing air cargo demand with air cargo supply can provide a first indication of certain market dynamics, a more in-depth research is required to understand the market dynamics better. Although there is a lack of integrator express data and a shortage of more disaggregated carried tonnes data, those two datasets are required to understand the complete market better.

Although the large extent and significant level of detail, the database has some shortcomings. First, the database assumes the maximum payload per aircraft type to estimate the ACT. By doing this, the database is guaranteed to be an overestimation of reality, as the maximum payload of an aircraft is seldom available. Second, the database excludes narrow-body passenger aircraft in all years and narrow-body freighter aircraft for the first four years. Last, due to missing flights on flight tracking websites and incomplete flight information, the cleaning progress filters out around 5% of all data causing imperfections in the dataset. To the best of our knowledge, this is the first work that introduces air cargo sales tonnes data and builds a comprehensive database based on three different flight tracking websites. As such, the data and insights could be extended and used in many ways. As airlines build their network on origin to final destination flows and utilise their hub and assets accordingly in providing capacity, the actual flow data is rather an aggregated outcome of cargo network decisions made by all airlines. For this reason, we believe that providing sales tonnes data rather than actual flow data will help managers, salespeople, network planners, etc., better to understand the origin and final destination of those flows in order to improve their decision-making. Although comparing actual flow data might be better suited, comparing sales tonnes data with the available capacity might provide decision-makers with a better understanding of which routes are over and underserved to adjust their capacity accordingly. Further research on actual flow data compared with sales tonnes data and the available capacity data might be desired to analyse the air cargo network and its flows.

Providing the availability of actual flown demand data, our sales tonnes data could be compared with the actual flown data to better understand the role of double-counting, transfers, and in-transit flights. Overall, the data allows for more future research on air cargo market dynamics of demand and supply on a more disaggregated level. Individual airline networks could be reconstructed, impacts, such as the Russian-Ukraine war, on certain airports or regions could be better isolated and analysed, evolutions in the market could be quantified, etc. Providing air cargo price data availability, the relationship between air cargo demand, supply and pricing could be better quantified. The impact of over- and under-capacity in the market on the price levels and route development might lead to a better understanding of the behaviour of airlines towards profit maximisation or decision-making. Another interesting research direction would be air cargo forecasting models. As current air cargo forecasting is mainly done on actual flow demand rather than sold demand, it might be an interesting perspective to forecast future sold demand and identify how the current networks need to be adapted. Next to air cargo forecasting, an integrated air cargo forecasting model for demand, supply, and price might be especially interesting for airline managers in allocating their assets, supporting them with network development problems, and making decisions on whether to buy or sell aircraft.

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