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Econometric analysis of the determinants of air cargo services supply in Latin America and the Caribbean

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ABSTRACT

This paper examines econometrically the determinants of air cargo supply in the countries of Latin American and the Caribbean (LAC) using city-pair data for 2011–2020. We find that air cargo supply tends to be concentrated in airports located in highly populated cities. The relationship between income and air cargo supply is more complex although its positive effect seems to be more consistent for dedicated cargo flights. In addition, we only find a negative relationship between distance and air cargo supply when we focus on belly cargo. Low-cost airlines spur cargo in passenger flights buy they do not have any positive role in dedicated cargo flights. Free trade agreements seem to contribute positively to a greater supply of air cargo, but this effect is concentrated on belly cargo and intra-regional routes. In contrast, the quality of the infrastructure at the airport of origin positively impacts air cargo supply only on dedicated flights and extra-regional routes. Finally, we do find evidence that a more intense competition between airlines and the greater use of wide-body aircraft have a positive effect on cargo supply.

1. Introduction

In this study, we carry out an econometric analysis of the determinants of supply of air cargo services in the countries of Latin American and the Caribbean (LAC). The analysis focuses on a region where most countries are middle income and air cargo is underdeveloped. The amount of air cargo per capita in LAC countries is three times lower than the world average (see figure A1 in the appendix). The countries of LAC face the dual challenge of increasing their integration into global chains – with the incorporation of products with greater value-added and with better access to more markets – and of boosting their intra-regional integration. Addressing these two challenges can contribute to the region's economic development.

This study seeks to examine the factors that can serve as an incentive to, and equally those that might limit, the transport of products by air, and thereby provide essential input for public policies aimed at promoting air cargo services. In this regard, the results of this study could be useful for other countries or regions, particularly those characterized by a low level of development of their air cargo sectors.

We analyze the determinants of air cargo services supply in LAC by estimating a model with data from the Official Airlines Guide (OAG) between city pairs and for airlines for the period 2011 to 2020. While many studies have examined the determinants of passenger traffic, the literature on air cargo is much scarcer and has tended to focus almost exclusively on demand flows in and from high income countries or in corridors of high traffic density. However, air freight transport plays an important role in the trade of high value-added products relative to their weight and, as such, it can play an equally important role in increasing a country's participation in higher value-added chains.[1] Several studies provide evidence that air cargo services can contribute significantly to economic growth (i.e. Button and Yuan, 2013; Brida et al., 2016; Brugnoli et al., 2018; Feyrer, 2019; Carbó and Graham, 2020). Our work is novel regarding the previous literature on air transport services supply that has mostly focused on passenger flights and the markets of United

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[1] According to data published by the United Nations on its Comtrade platform, the main air cargo exports of the LAC countries include product categories with a high value relative to their weight: that is, jewelry (natural pearls); electronic, audiovisual, and photographic equipment; pharmaceuticals; medical equipment; and aircraft and parts thereof. In LAC, the air cargo export of perishable goods – including fruit, meat, fish, and shellfish – and household and office (but not audiovisual) items is also notable, albeit they constitute a smaller quota of the total.

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States and Europe. Hence, this study constitutes an important step forward in acquiring a deeper knowledge of this strategic sector in middle-income countries. We use a multivariate econometric model that allow quantitative identification of influences on the supply of air cargo services on an origin/destination basis.

Previous studies on air cargo focus on demand by estimating a gravity model that consider population, income, and distance as the main explanatory variables (eg; (Matsumoto, 2007; Alexander and Merkert, 2017; Gong et al., 2018; Hwang and Shiao, 2011; Matsumoto and Domae, 2018, 2019). The analysis of air transport supply has focused on passenger flights considering demand shifters and the intensity of competition as the main explanatory variables (eg; Schipper et al., 2002; Richard, 2003; Bettini and Oliveira, 2008; Fageda and Flores-Fillol, 2012; Fageda, 2014; Calzada and Fageda, 2019; Brueckner and Luo, 2014).

Adding to previous studies, we simultaneously examine the influence of a broad set of factors for a period spanning ten years on the supply of air cargo services. Together with the variables typically employed in demand analyses, here we consider factors like the intensity of competition, the type of airline operating the route (i.e. network vs low-cost airlines), the use of wide-body aircrafts, free trade agreements or the quality of the infrastructure at the origin. Furthermore, we analyze the differences between 'belly' cargo (carried in the hold of an aircraft mainly devoted to passengers) and that on dedicated cargo flights (cargo-only) and differences between intra-regional routes (flights between LAC cities) and extra-regional routes (flights between a LAC and a non-LAC city). The main challenge is to show the influence of supply factors and not just to predict demand.

We find that the supply of air cargo services tends to be concentrated in airports located in highly populated cities. This is the case whatever the sample we consider. The relationship between income and air cargo supply is more complex although its positive effect seems to be more consistent for dedicated cargo flights. In addition, we find a weak influence of distance on dedicated cargo flights for which lower demand in longer routes may be compensated by a higher competitiveness of air transportation in comparison to other transport modes.

Low-cost airlines spur cargo in passenger flights buy they do not have any positive role in dedicated cargo flights. Free trade agreements seem to contribute positively to a greater supply of air cargo, but surprisingly this effect is concentrated on belly cargo and intra-regional routes. To this point, many trade agreements were signed long before the start of the period considered in this study, which could distort the identification of their effect on extra-regional routes. In contrast, the quality of the infrastructure at the airport of origin positively impacts air cargo services supply only on dedicated cargo flights and extra-regional routes. Finally, we find that a more intense competition between airlines and a greater use of wide-body aircraft have a positive effect on cargo services supply.

The rest of the paper is structured as follows. In section 2, we review the previous literature that is related to our study. In the next section, we describe the data and specify the econometric model that is to be estimated. We then show the outcomes of the estimates and discuss these results. The last section is dedicated to discussing the policy and management implications that emerge from the results of the preceding analysis.

2. Literature review

The academic literature examining the determinants of air cargo services is scarce compared to the legion of extant studies that analyze passenger traffic. Most studies focus on air cargo demand, which limits the analyses to a specific case study or use country-level data. As in the analysis of passenger traffic, the most common type of study conducted to examine the determinants of air cargo demand involves estimating a gravity model using bilateral data, usually between countries. Gravity models assume that the demand between two points depends positively on the economic and demographic size of these two points, and negatively on the distance between them. Therefore, as mentioned above, these models usually have as their dependent variable the volume of cargo transported between two countries and as their explanatory variables the mean distance of the route, Gross Domestic Product (GDP) per capita, and the population of the countries or cities that constitute the route's origin and destination.

Demand prediction may differ from the supply analysis developed in this paper. First, supply data is richer and more detailed than demand data, at least when we analyze air cargo services. Demand analyses usually rely on aggregated data at the country level. In contrast, our supply analysis uses data at the airline and city-pair level. Second, supply will not be necessarily equal to potential demand because airlines may be operating with a different degree of excess of capacity depending on the specific route and airline attributes. Third, demand analyses do not distinguish between dedicated cargo flights and belly cargo nor between extra-regional and intra-regional routes.

In a study centered on dense routes in Asia, Europe and America, Matsumoto (2007) reports that GDP has a modest effect on air cargo. In contrast, Alexander and Merkert (2017) and Gong et al. (2018) find that air freight is heavily dependent on GDP in studies for Australia and China, respectively. In Matsumoto's (2007) study, population has a greater effect on freight traffic than it has on passenger traffic. Likewise, Hwang and Shiao (2011), in a study of the international airport of Taiwan, shows that the population of the destination city is one of the main determinants of air cargo flows. In a study focused on Asian airports, Matsumoto and Domae (2018) find that population and GDP have a greater influence on cargo traffic than on passenger traffic, although a subsequent study by the same authors shows that the influence of both variables decreases over time (Matsumoto and Domae, 2019).

A common finding in this literature is that distance is a more important determinant of passenger traffic than it is of freight traffic. In the case of passenger traffic, distance always has a negative and statistically significant effect, except in studies that focus on short-haul routes where the role of intermodal competition is more relevant. In the case of air cargo traffic, the results regarding the effect of distance are mixed; some studies find a negative and significant effect – although the impact is never as great as it is with passenger traffic (Matsumoto, 2007; Alexander and Merkert, 2007), others find a modest effect (Yamaguchi, 2008), while some even report a positive effect (Matsumoto and Domae, 2018).

When the data are available, other explanatory variables are typically included: for example, some indicator of the costs of transporting cargo by plane or the degree of liberalization of the air market between the two countries. A common result in those few studies that have sufficient information is that higher prices or costs for airlines are associated with lower flows of air cargo. This is the main result reported by Turner (2001) for routes originating in Vancouver, by Yamaguchi (2008) for traffic between the United States and countries in the rest of the world, and by Hwang and Shiao (2011) for Taiwan. Another common finding is that a higher degree of liberalization of air transport leads to an increase in air cargo, an outcome reported both for the United States (Achard et al., 2009; Micco and Serebrisky, 2006; Yamaguchi, 2008) and Taiwan (Hwang and Shiao, 2011). Some other studies focus their attention on specific aspects that have an important influence on air cargo, such as the role of intermodal competition (Chen and Jiang, 2020; Alexander and Merkert, 2021), the quality of infrastructure (Gadala-Maria, 2014), and whether the cargo flows are associated with countries that are parties to a trade agreement (Hwang and Shiao, 2011). While these previous analyses focus on demand, our supply analysis may have some advantages or provide additional insights. As we will explain below, supply models do not consider fares as explanatory factor. In contrast, demand models should include fares as covariate but fare data are usually not available. Furthermore, our supply analysis allows us to examine whether competition (both intramodal and intermodal) may lead airlines to operate with excess of capacity.

Finally, the quality of the infrastructure may have a more direct influence on supply than on demand.

Another line of research that should be highlighted is that which analyzes the relationship between GDP and air cargo by estimating dynamic models that allow the identification of Granger causality. Results here vary according to the country or the geographical area analyzed. Chang and Chang (2009) and Marazzo et al. (2010) find evidence of a bidirectional relationship between air cargo and GDP in studies for Taiwan and Brazil, respectively. However, the causality is stronger in the direction that runs from GDP to air cargo than that which runs from air cargo to GDP. In contrast, Hakim and Merkert (2016) and Tolcha et al. (2020) find evidence of a unidirectional relationship running from GDP to air cargo in a study of countries in South Asia and sub-Saharan Africa (except Ethiopia, where the unidirectional relationship is inverted). Choi (2023) and Choi and Park (2020) provide evidence that the link between GDP and air cargo has been weakened in their analysis for South Korea. In this regard, they find evidence of a causal relationship for 2001–2009 but not for 2010–2018. This could be explained by a paradigm shift from a supplier-oriented market to one in which consumer preferences plays a major role. To this point, we develop a similar analysis here for LAC countries, which is complementary to the main supply analysis, to examine in more detail the role of GDP on air cargo services.

On the other hand, several studies have examined the determinants of air transport services supply in commercial passenger flights.[2] The variable of interest in these studies is the number of seats or the number of flights between pairs of countries, cities, or airports. In these studies, it is commonly assumed that airlines first make supply decisions and then they adjust fares according to the evolution of demand. Indeed, airline decision-making is modeled in a multi-stage process. In the first stage, the airlines decide which routes to operate and at what capacity (i.e. frequencies, type of aircraft, etc.). In the second stage, they fix their prices based on this capacity and the evolution in demand. Hence, fares are not considered to be an explanatory variable in supply equations.[3] By contrast, demand shifters (population, income, distance) and the intensity of competition are typically considered major determinants for airlines' supply choices.

Examples of studies that estimate supply equations at the route level and find positive relevant effects of income and population include Bettini and Oliveira (2008), Bilotkach et al. (2010), Pai (2009), Fageda and Flores-Fillol (2012), Brueckner and Luo (2014), Fageda (2014) and Calzada and Fageda (2019). Such positive effects can be explained by the higher demand that can be expected in routes that connect richer and more populated endpoints. Airlines react to higher demand by increasing supply (increasing both the frequency of flight and the size of the aircraft). The only study on air transport supply that consider cargo is Wang et al. (2021). They develop a Bayesian network analysis to 46 large cities. Their most remarkable result is that GDP is more relevant in explaining passenger than cargo volumes even though GDP is also a relevant factor in explaining cargo.

Another common result is to find a negative relationship between distance and flight frequency, and a positive relationship between distance and aircraft size being the net effect of the distance on the total supply negative (Pai, 2009; Bilotkach et al., 2010; Brueckner and Luo, 2014; Calzada and Fageda, 2019). Longer routes imply less demand and airlines are less exposed to competition from other transport modes.

Furthermore, it is well established in the literature, both theoretically and empirically, that airlines compete in capacities (eg; Berry and Jia, 2010; Bilotkach et al., 2010; Brueckner, 2004; Brueckner and Flores-Fillol, 2007; Brueckner and Luo, 2014; Schipper et al., 2002; Richard, 2003; Brueckner and Flores-Fillol, 2020; Czerny et al., 2021). Finally, results are mixed regarding the influence of the type of airline. In studies for Europe, it has been found that low-cost airlines tend to operate with lower frequencies than network airlines although this result could be explained by the fact that low-cost airlines tend to operate in lower demand routes (Fageda and Flores-Fillol, 2012; Calzada and Fageda, 2019). In contrast, Bettini and Oliveira (2008) find that Gol's presence in the Brazilian market implies a greater supply of seats although they suggest that this could be related with the entry of Gol in dense markets. In a similar vein, Pai (2009) in a study for United States shows that low-cost airlines provide a greater supply than non-low-cost carriers and that supply is higher in hubs (dominated by network carriers).

The present study contributes to the literature by making a comprehensive analysis of the determinants of supply of air cargo services in a region where most countries are middle income, and the air cargo sector is underdeveloped. The focus on supply allows us to consider a wide set of variables, beyond those typically employed in previous studies on demand. Previous studies estimating a demand equation using a gravity model usually just consider population, GDP and distance as main regressors. In this regard, demand data at the airline-route level are generally not available. In this study, we can provide novel insights about the role of the type of the airline (ie; network vs low-cost carriers), the intensity of airline competition in the route, the use of wide-body aircrafts or the quality of the infrastructure (at the airport level) on the supply of air cargo services.

Given that most of demand studies on cargo services rely on data at the country level, results for variables like distance or population may mask a high heterogeneity when the considered country is big. Otherwise, we consider the population of the cities that are the origin and destination of the route and the distance between the two airports that serve those cities.

Furthermore, we can analyze differences between belly cargo and dedicated cargo flights and differences between intra- and extra-regional flights that studies using demand data on cargo services cannot do due to data limitations.

Since supply is highly correlated with demand, we can expect similar results for most of the variables considered in our supply analysis of cargo services with respect to what we would obtain in a demand analysis of cargo services (if we had demand data to carry out the analysis that we carry out in this study).

However, supply will not be necessarily equal to potential demand because airlines may be operating with a different degree of excess of capacity depending on the specific route and airline attributes. For example, higher levels of competition (either intra-modal or intermodal) may lead airlines to operate with greater excess capacity. Low-cost airlines can stimulate passenger demand by offering lower prices, but it is uncertain whether this greater demand is absorbed with higher load factors or a greater supply, and it is also uncertain how this will affect the supply of cargo services. On the other hand, the quality of the infrastructure should have a more direct effect on supply to the extent that its impact on demand is expected to be indirect through higher supply. Also, airline decisions on capacity are usually made in a longer timeframe as it involves availability of equipment, personnel and routes and not necessarily react quickly to short term demand variations. Finally, airlines' choices regarding aircraft type and flight frequency may have different implications in terms of operating with excess of capacity.

Note also that we may expect some differences in the results of the variables considered in our model when we make the distinction between belly cargo and cargo in dedicated cargo flights, a distinction that cannot be made in studies that use demand data. Belly cargo is

[2] Some studies examine the influence that airline supply choices may have on demand (Richard, 2003; Wei and Hansen, 2005; Wei and Hansen, 2007). It is found that flight frequency has a stronger influence than aircraft size on demand.

[3] Note also that variables of the price or cost of air cargo cannot be considered due to a lack of data. Competition variables can indirectly approximate the effect of costs insofar as less competition is expected to be associated with higher costs.

conditioned by the demand of passenger's services and the strategies that airlines may follow in the passenger's market. Cargo in dedicated cargo flights is more linked to trade-flows and the specific strategies followed by air cargo freighters. In the latter case, we should not expect any direct influence of the passenger's market.

3. Data and the model

The econometric analysis is based on data provided by the Official Airlines Guide (OAG) that have a LAC country as origin or destination. We have collected annual data for city pairs and airlines for the period from 2011 to 2020. The route is considered as being between city pairs; therefore, in cities with more than one airport we collapse the information at the city level. The OAG lists the names of all airports and their corresponding cities. We only consider those flights that offer cargo capacity greater than zero, and the data frequency is annual. Note, moreover, that we consider routes in both directions, that is, for example, the Buenos Aires–Sao Paulo route is treated separately from the Sao Paulo–Buenos Aires route. In the case of passenger transport, the supply in both directions is usually the same; however, in the case of cargo transport, there are usually marked differences between the supply of cargo in one direction and that in the other. This explains why we opt to treat them separately.

The analysis focuses on cargo services supply of the airlines between cities, based on the information provided by the OAG, which moreover codes airlines that identify as low-cost carriers. The guide also provides information about the type of service and as to whether they are dedicated cargo flights. Finally, information is provided about the distance of the route and the type of aircraft used to make the flight. Information is crossed from other databases for some of the other explanatory variables, the case of population, GDP, and free trade agreements.

The sample includes all routes with the rest of the world that have their origin and/or destination in the cities of LAC. In total, 19,095 airline-route pairs are considered although data may not be complete for some variables, and we exclude airline-route pairs with less than one flight per month. The structure of our data is a panel because we have repeated observations over time of airline-route pairs. However, the panel is unbalanced because the different airline-route pairs are observed a different number of years as many airline-route pairs may not have cargo services during certain years of the period considered (recall, only the airline-route pairs with a cargo supply greater than zero count as observations).

The model we estimate for airline *a* and route *r* in year *y* can be expressed as follows:

$$Air\_cargo_{ary} = \alpha + \beta_1 Distance_r + \beta_2 GDP\_origin_{ry} + \beta_3 GDP\_arrival_{ry} + \beta_4 Population\_origin_{ry} + \beta_5 Population\_arrival_{ry} + \beta_6 LCC\_airlines_a + \beta_7 Network\_airlines(hub\_origin)_a + \beta_8 Network\_airlines(hub\_arrival)_a + \beta_9 HHI_{ry} + \beta_{10}\%\ wide\text{-}body\_flights_{ary} + \beta_{11} Trade\_block_{ry} + \beta_{12} Intra\text{-}regional\ flights_r + \beta_{13} Landlocked\ country_r + \beta_{14} Frequency\ (1\text{–}2\ daily\ flights)_{ry} + \beta_{15} Frequency\ (>2\ daily\ flights)_r + \rho_y + \varepsilon_{ary}$$

The dependent variable is the total number of metric tons of freight carrying capacity per year provided by airlines on the route, including belly cargo (in the holds of passenger flights) and dedicated cargo flights.

As explanatory variables, we include typical demand shifters in aviation studies: namely, the distance of the route, population of the cities of origin and destination, and GDP per capita of the countries of origin and destination of the route.

GDP data are at the country not the city level. Although GDP data at the city level are not available, using data at the country level has the advantage of mitigating the potential endogeneity problem derived from the simultaneous relationship that might exist between air cargo and economic activity.[4] GDP data are taken from the World Bank website (World Development Indicators). We also consider the (urban area) population of the cities of origin and destination of the route, although the information is only available for urban areas with more than 300,000 inhabitants. Urban population data are taken from the United Nations website (World Urbanization Prospects).

Given the strong correlation between demand and supply, we expect that the variables that impact demand will affect supply in a similar way. Thus, we expect a positive effect of the population and GDP variables on the supply of air cargo services insofar as routes that connect a country's most populated cities and those with the highest volume of economic activity should generate more demand.

The expected effect of the distance variable is not clear a priori. In analyses of demand for air passenger transport, it is typical to expect a negative effect of distance insofar as demand from/to more distant destinations is lower than that from/to closer destinations. A sizeable part of air freight is transported in the holds of airplanes destined mainly for passenger traffic and, given that distance has a negative impact on passenger demand, it may also have an indirect negative effect on air cargo supply. We should also expect a deterrence effect of distance on trade by air (Hummels, 2007; Hummels and Schaur, 2013). However, there is no previous evidence on whether demand in dedicated cargo flights is lower in longer routes.

In analyses of air transport supply for passenger flights, a negative relationship between frequencies and distance is generally found. Airlines set lower frequencies (and hence reduce supply) in longer routes due to less demand but also because they are less exposed to intermodal competition. However, flight frequency could be a less relevant variable in the competition between air freighters, ships and trucks in short-haul routes. Our data indicate that the negative correlation between distance and frequencies is much higher for passenger flights (−0.19) than for dedicated cargo flights (−0.06).

In the case of air cargo services, we also need to consider that the plane is generally an expensive means of transport compared to the ship or truck for transporting merchandise while the advantage of air travel is speed and reliability in terms of travel time. In this regard, the relative competitiveness of air transport increases with distance (Harrigan, 2005; Hummels, 2007).

Thus, the net impact of distance on supply that comes from demand is not clear because the effect of the increased attractiveness of air may or not dominate the deterrent effect that we may expect of distance on trade and passenger flights. Differences between belly cargo and cargo dedicated flights may also come from the different reactions of airlines in terms of frequencies to less competition from other transportation modes.

We also include, as explanatory variables, two dummy variables that identify whether the airline offering the service is a network or a low-cost airline. We consider network airlines (operating at their hub airports as announced in their websites) as those that are integrated in one of the three international alliances (Oneworld, Star, SkyTeam). Low-cost airlines are codified by the data provider itself (OAG) and this classification coincides with that established by the International Civil Aviation Organization (ICAO). In our sample, we consider the following airlines

[4] The analysis we undertake in Appendix B of the causal relationship between air cargo and economic activity suggests that the potential problem of endogeneity is modest insofar as economic activity is a much stronger determinant of air cargo than air cargo is of GDP. Endogeneity is even less of a problem if we consider the specific supply between two cities as the dependent variable and the aggregate GDP of the two countries as the explanatory variable.

to be low cost: Aerolineas Sosa, Allegiant, Azul Airlines, Eurowings, Frontier, Interjet, Jetairfly, Jetblue, Norwegian, Sky, Southwest, Spirit Airlines, Star Peru, Sun Country Airlines, Virgin America, Viva Air Colombia, Viva Air Peru, and Volaris.[5] The expected effect of these variables is not obvious a priori, although it is interesting to see the extent to which the type of airline offering the service might affect the supply of air cargo services. The airlines that cannot be classified as either network or low-cost airlines include regional airlines that operate with small aircraft (regional jets or turboprops), charter airlines, cargo airlines and airlines with a hybrid business model.

Other route attributes are also included, most notably the Herfindahl-Hirschman index (HHI), which measures the intensity of competition on the route in terms of cargo supply based on the sum of the squares of the share of the airlines operating on the route. The values of HHI ranges from 0 (intense competition) to 1 (monopoly). Airlines compete in price, but they also compete in capacity, which means less competition can result in less supply. Note also that less competition could also be consequence of less demand. Hence, we expect a negative sign of the coefficient associated to the HHI variable.

We also include a variable that measures the percentage of flights on the route in which the airline uses wide-body aircraft.[6] Wide-body aircrafts have a greater hold capacity (and palletizable) than smaller aircrafts, which facilitates transport and operator efficiency. Thus, we expect a positive effect of this variable.

Additional variables that are considered are a dummy variable that takes a value of 1 for routes that link countries of origin and destination that are parties to a free trade agreement, including interregional and regional agreements. Free trade agreements always imply the liberalization of trade in goods, and some also include the liberalization of trade in services and the coordination or unification of trade policy with respect to countries that are not party to the agreement. We expect a positive effect of this variable given that greater liberalization should stimulate trade and, hence, the total volume of cargo transported (which to some extent is likely to result in greater air cargo services supply). Table A1 in Appendix A shows the multilateral trade agreements between Latin American countries. There are 13 such agreements, although several countries are party to more than one. Additionally, several countries have signed bilateral agreements with other countries. The country with the most bilateral agreements in Latin America is Chile. Countries such as Colombia, Panama and, to a lesser extent, Costa Rica, Peru, and Mexico are also party to several active agreements.

Another variable that we consider is a dummy for intra-regional routes, that is, routes that connect LAC cities. The interest of this variable lies in examining whether the supply, is greater on intra-regional than it is on extra-regional flights, considering the values of the rest of the explanatory variables, including distance and other attributes of the airline-route pair.

A specific characteristic of the country of origin and destination of the route that we consider is whether it is landlocked or not. We would expect air cargo services supply to be higher in landlocked countries as shipping ceases to be a relevant competitor of the aircraft. Thus, the expected effect of this variable is positive. That said, the number of landlocked countries in the sample is actually very small: Austria, Azerbaijan, Belarus, Bolivia, Ethiopia, Kazakhstan, Paraguay, Switzerland, and Uzbekistan.[7]

In addition, we include two dummy variables for flights with a high frequency of service. First, a dummy variable that takes a value of 1 for airline-route pairs with between one and two daily flights, and a dummy variable that takes a value 1 for airline-route pairs with more than two daily flights. We expect these variables to have a positive effect for belly cargo, but it is less clear the expected result for dedicated cargo flights.

In some regressions, we include additional variables that can capture the quality of the infrastructure at the airports in the city of departure. First, we consider a variable that measures the total number of cargo tons from the departure airport(s) that is only available when the city of departure is from a LAC country. We assume here that airports with a greater volume of cargo are likely to have better customized facilities for handling air cargo. Second, we consider a variable that measures the quality of the specific cargo facilities at the airport (on the apron at the foot of the aircraft, customer service areas, interface areas with inland transportation, normal cargo warehouses, warehouse facilities for hazardous and valuable cargo, refrigerated and perishable goods facilities, security control facilities, dedicated areas for customs control) as reported by the main airlines in the region in a survey conducted by the Inter-American Development Bank (IDB) with data from 2019.[8] It should be noted that this variable has limitations inasmuch as it refers to just 30 airports for the year 2019. Therefore, it is assumed that there is no variation across the period considered and the regressions with this variable only take into consideration these 30 airports. Note that data limitations of these variables prevent us from include them in the baseline model.

Given that the dataset has the structure of a panel, we could estimate a fixed or random effects model. However, the fixed effects model does not allow to capture the effect of time-invariant variables like distance or the dummies for intra-region routes and landlocked countries. It could also not identify properly the effect of variables with low time variability like income or population. However, we consider a fixed effect model at the route level to analyze in more detail the effect of trade block agreements and the entry of low-cost airlines because there are changes in the period considered in some routes in the sense that they go from not being affected to being affected by free trade agreements or the entry of low-cost airlines. The expected correlation between random effects and the explanatory variables advises against using this model although results are like the ones obtained in the pooled model that we estimate.[9]

All continuous variables presenting positive values (without zeros) are log transformed, which allows the interpretation of the coefficients as elasticities and reduces the influence of any outliers. Time dummies (ρy) are also included to capture temporary shocks that may be common to all countries/routes. For example, the period considered includes the year 2020 with the consequent impact of the Covid-19 pandemic.

Finally, the error term is assumed to be independently and identically distributed with zero mean and constant variance. This means the standard errors are robust to any problem of heteroscedasticity and clustering is applied at the route level to control for any problem of spatial or temporal autocorrelation.

Table 1 provides descriptions of the variables used, the data source,

[5] GOL is considered by both OAG and ICAO as a low-cost airline. However, its business model and average price level differ from those of what are typically classified as low-cost carriers. Therefore, we exclude it from the low-cost category. However, the results of the variable do not change if we consider it as low cost.

[6] The primary data is at the flight level (ie; the flight 2264 of American Airlines from Acapulco to Dallas Forth Worth) and include the information of the type of aircraft used that is classified as piston, turboprop, regional jet, narrowbody and widebody. The final dataset is collapsed at the airline-route level and we can calculate the total number of flights and the number of flights that use wide-body aircrafts in each airline-route pair.

[7] In the case of Paraguay, while it has no direct access to the sea, it has a connection via the *hidrovía* and the transhipment ports of Buenos Aires or Montevideo, so that river/maritime transport is an option.

[8] *Logistics in Latin America and the Caribbean: opportunities, challenges, and courses of action*, Agustina Calatayud & Laureen Montes, eds. Inter-American Development Bank, 2021.

[9] In random effects models, the error term includes a specific component that is specific to each airline-route pair of the sample. We may expect that this specific component is correlated with covariates that identify different route and airline attributes. The correlation between the error term and the covariates may impose a bias to the estimation.

Table 1
Description and basic statistics of the variables used in the econometric analysis.

Variable	Description of variable	Source	Mean	Standard deviation	Minimum value	Maximum value
Air_cargo	Air cargo (Total metric tons available): belly + dedicated	Official Airlines Guide (OAG)	1657.219	3291.117	0.4	83,041.3
Distance	Distance (number of kilometers)	OAG	2186.216	2344.578	92	18,919
GDP_origin	GDP_origin (Gross domestic product in dollars of countries of origin)	World Bank	19,680.27	18,383.6	618.18	111,290.1
GDP_arrival	GDP_arrival (Gross domestic product in dollars of countries of arrival)	World Bank	19,460.27	18,245.77	366.66	111.290.1
Population_origin	Population_origin ('000s of inhabitants in urban areas of origin)	United Nations	5777.989	6304.721	261.524	37,468.3
Population_arrival	Population_arrival ('000s of inhabitants in urban areas of arrival)	United Nations	5706.45	6258.794	261.524	37,468.3
LCC_airlines	Low cost airlines (dummy. Value 1 if airline is low cost carrier according to OAG classification)	OAG	0.196	0.397	0	1
Network_airlines (hub_origin)	Network airlines, hub_origin (dummy. Value 1 if airline is in an alliance and the origin is one of its hub airports)	OAG	0.131	0.338	0	1
Network_airlines (hub_arrival)	Network airlines, hub_destination (dummy. Value 1 if airline is in an alliance and the destination is one of its hub airports)	OAG	0.131	0.337	0	1
HHI	HHI (Concentration index based on the total cargo traffic on route)	OAG	0.721	0.259	0.123	1
% wide-body_flights	% wide-body flights (percentage of total flights using wide- body aircraft)	OAG	0.189	0.387	0	1
Trade_block	Trade block (dummy)	World Trade Organization	0.540	0.498	0	1
Intra-regional flights	Intra-regional flights (dummy. Value 1 if origin and destination are both in Latin America and Caribbean)	OAG	0.574	0.494	0	1
Landlocked country	Landlocked country (dummy. Value 1 if the country of origin and/or arrival has no outlet to the sea)	Google Maps	0.021	0.144	0	1
Frequency (1–2 daily flights)	Frequency, 1–2 daily flights (dummy. Value 1 if between one and two flights a day)	OAG	0.085	0.279	0	1
Frequency (>2 daily flights)	Frequency, >2 daily flights (dummy. Value 1 if more than two flights a day)	OAG	0.040	0.197	0	1
Total cargo at departure airport	Total metric tons at departure airport	OAG	104,198.2	154,758.8	0.4	815,854.5
Infrastructure quality index	Infrastructure quality (index from 1 to 5)	Airline survey - IDB	3.548	0.666	1.1	4.3

and their mean and standard deviation values. In general, the standard deviation is high in relation to the mean, which implies that there is sufficient variation in the case of all the variables. For the average route, the annual supply of an airline on that route is around 1600 freight tons and the distance traveled is around 2200 km. As such, the average route can be considered a medium-haul route. The mean urban area population is high, more than 5 million inhabitants, taking into account the considerable variation presented by the variable and that cities with fewer than 300,000 inhabitants are excluded. That said, air cargo seems to concentrate in highly populated cities. It is also noteworthy that around 20% of the observations refer to low-cost airlines, and that more than half the observations refer to intra-regional flights and flights between countries that are trading partners. The mean concentration level (HHI) is high, which suggests that the intensity of competition is low. It should also be noted that only 2% of the observations include routes to or from a landlocked country.

Table A2 in Appendix A shows the correlation matrix of the variables used in the empirical analysis. In relation to the dependent variable, the (positive) correlation is especially high with the variables of population, percentage of wide body aircrafts and high frequencies. In relation to the explanatory variables, the positive correlation is high between the distance variables and the wide-body and intra-regional flight dummy variables. Additionally, we find a strong negative correlation between the intra-regional flight variable and GDP, which may be attributed to the fact that extra-regional flights frequently connect with the high-income countries of North America and Europe. In addition, correlation between the intra-regional and trade block variables is low. Although some of the variables are highly correlated, the estimated variance inflation factors – which could indicate a problem of multicollinearity – are very low, with values below 2 in almost all cases and below 3 for all variables (a value of 5 is considered the threshold for a multicollinearity problem). We report results with different specifications of equation (1) considering different subsets of variables to identify any potential distortion due to the correlation between some of the explanatory variables.

4. Results

Table 2 shows the results of the estimates. In model (1), we show the results when only the demand shifters typically employed in gravity models are included as covariates; Distance, GDP per capita at origin and arrival, and population at origin and arrival. In model (2), we just consider airline and route attributes; the type of airline, the HHI variable and the percentage of flights operated with wide body aircrafts. The model (3) jointly considers the demand shifters and the airline/route attributes. The model (4) considers a regression that add other variables; the dummy for trade agreements, the dummy for intra-regional flights and the dummy for landlocked countries. The last model also includes the dummies for high-frequency services.

In all regressions, we find a negative impact of distance. Thus, air cargo supply is lower in longer routes as it has been found in previous studies on passenger flights. We also find a positive impact of population (both at the origin and arrival) on air cargo supply in all regressions, providing evidence that air cargo tends to be concentrated in airports located in highly populated cities. The effect of the GDP variables is less clear given that they are only statistically significant when we consider trade block, intra-regional and landlocked variables.

In Appendix B, we explore in more detail the relationship between air cargo and GDP using the Granger causality test applied to the sample containing all the countries presenting the complete data series and to each of these countries separately. In the first of these analyses, that is for the whole set of countries, we find evidence of a bidirectional relationship between GDP and air cargo, although the impact is more relevant, both in terms of statistical significance and magnitude of the

Table 2
Results of the estimates (dependent variable: cargo capacity – metric tons. All flights).

VARIABLES	(1)	(2)	(3)	(4)	(5)
Distance	−0.143***		−0.292***	−0.208***	−0.0760***
	(0.0229)		(0.0232)	(0.0252)	(0.0210)
GDP_origin	0.00767		0.00189	0.141***	0.0827**
	(0.0290)		(0.0258)	(0.0358)	(0.0324)
GDP_arrival	−0.0163		−0.0185	0.119***	0.0602*
	(0.0282)		(0.0255)	(0.0355)	(0.0323)
Population_origin	0.322***		0.263***	0.241***	0.176***
	(0.0172)		(0.0165)	(0.0164)	(0.0143)
Population_arrival	0.306***		0.251***	0.231***	0.167***
	(0.0171)		(0.0164)	(0.0163)	(0.0142)
LCC_airlines		0.726***	0.432***	0.432***	0.347***
		(0.0266)	(0.0339)	(0.0346)	(0.0307)
Network_airlines (hub_origin)		0.208***	−0.0675	−0.0235	−0.115***
		(0.0343)	(0.0423)	(0.0432)	(0.0376)
Network_airlines (hub_arrival)		0.208***	−0.0524	−0.00872	−0.0832**
		(0.0350)	(0.0446)	(0.0454)	(0.0390)
HHI		−1.175***	−0.522***	−0.539***	−0.427***
		(0.0565)	(0.0598)	(0.0608)	(0.0534)
% wide-body flights		1.040***	1.053***	1.171***	1.259***
		(0.0368)	(0.0475)	(0.0488)	(0.0454)
Trade block				0.227***	0.163***
				(0.0377)	(0.0329)
Intra-regional flights				0.515***	0.379***
				(0.0707)	(0.0634)
Landlocked				0.229*	−0.0551
				(0.131)	(0.0976)
Frequency (1–2 daily flights)					1.546***
					(0.0267)
Frequency (>2 daily flights)					2.235***
					(0.0441)
Constant	3.048***	7.028***	5.184***	1.834***	2.697***
	(0.404)	(0.0644)	(0.393)	(0.646)	(0.569)
Observations	26,820	52,751	26,820	26,820	26,820
R-squared	0.129	0.138	0.203	0.214	0.358

Notes: Standard errors in parentheses (robust to heteroscedasticity and applying clusters at the route level). Statistically significant at 1% (***), 5% (**) and 10% (*). All regressions include year dummies.

coefficients, in the direction that runs from GDP to air cargo than that which runs from air cargo to GDP. This result is consistent with findings reported in previous studies, especially those dedicated to the study of middle-income countries. That said, there is a considerable degree of heterogeneity across the countries and the results of the econometric analysis for the set of countries appear to be determined by the specific effects in just a few, most notably Chile. Indeed, the causal relationship between GDP and air cargo is weak in most countries in the region.

The coefficients of the dummy variable that identify low-cost airlines is positive and statistically significant in all regressions. To this point, it should be noted that many of the low-cost airlines in the sample operate in very large markets (e.g. Brazil, the United States and Europe). Therefore, it is unclear as to whether in other contexts the same positive effect would be obtained. Additionally, low-cost airlines typically do not operate with wide-body aircraft. In this regard, the coefficient of the variable that identifies the greater use of wide-body aircraft is positive and statistically significant in all the regressions. Results for network carriers are mixed and it seems that the sign of the coefficient depends on the variables included in the model, particularly if the variables of frequencies are considered or not. Similarly, the coefficient of the variable that identifies landlocked countries is positive and statistically significant only if frequency variables are included or not.

The coefficient of the variable that measures the intensity of competition (HHI) is negative and statistically significant in all the regressions. Less competition implies lower supply, which suggests that airlines compete not only in price but also in capacity. However, note also that lower demand will imply lower supply and therefore less interest to compete. In addition, and as might be expected, supply is greater on routes with a high frequency of flights, the corresponding variable being positive and statistically significant in all the regressions.

The dummy variable that identifies intra-regional flights is positive and statistically significant in all regressions. This allows us to conclude that there is greater integration between the countries of the LAC region than with countries from other regions, at least as far as air transport supply is concerned. Another result worth highlighting is that the coefficient of the dummy variable identifying routes between countries that are trading partners is positive and statistically significant in all the regressions.

Tables 3 and 4 replicates the previous analysis but making the distinction between belly cargo (in the holds of passenger flights) and cargo from dedicated cargo flights. Table 3 focuses on belly cargo, while Table 4 is centered on dedicated cargo flights. As we mention above, we may expect some differences between both types of cargo services. Belly cargo is conditioned by the demand of passenger's services and the strategies that airlines may follow in the passenger's market. Cargo in dedicated cargo flights is more linked to trade-flows and the specific strategies followed by air cargo freighters. In the latter case, we should not expect any direct influence of the passenger's market.

Results for belly cargo are like those found in regressions shown in Table 2. The main difference is that the coefficients of the dummy variables for network carriers are now positive and statistically significant in all regressions.

Table 4 only consider the supply provided on dedicated cargo flights. First, the coefficient of the distance variable becomes positive although it is only statistically significant when we just consider gravity variables and when we consider all variables including frequencies. In a similar vein, the dummy for intra-regional routes is not statistically significant. Thus, we do not find any evidence of a negative relationship between

Table 3
Results of the estimates (dependent variable: cargo capacity – metric tons. Belly cargo).

VARIABLES	(1)	(2)	(3)	(4)	(5)
Distance	−0.155***		−0.242***	−0.143***	0.0384**
	(0.0231)		(0.0259)	(0.0269)	(0.0190)
GDP_origin	−0.0194		−0.0388	0.143***	0.0719***
	(0.0255)		(0.0245)	(0.0310)	(0.0250)
GDP_arrival	−0.0252		−0.0453*	0.137***	0.0688***
	(0.0258)		(0.0247)	(0.0315)	(0.0257)
Population_origin	0.307***		0.258***	0.232***	0.148***
	(0.0165)		(0.0165)	(0.0160)	(0.0122)
Population_arrival	0.294***		0.245***	0.219***	0.138***
	(0.0163)		(0.0163)	(0.0157)	(0.0119)
LCC_airlines		0.890***	0.654***	0.674***	0.637***
		(0.0263)	(0.0327)	(0.0328)	(0.0274)
Network_airlines (hub_origin)		0.438***	0.209***	0.279***	0.247***
		(0.0348)	(0.0442)	(0.0443)	(0.0358)
Network_airlines (hub_arrival)		0.438***	0.217***	0.286***	0.268***
		(0.0354)	(0.0452)	(0.0449)	(0.0364)
HHI		−1.022***	−0.468***	−0.490***	−0.307***
		(0.0533)	(0.0575)	(0.0582)	(0.0461)
% wide-body flights		0.642***	0.666***	0.857***	0.852***
		(0.0322)	(0.0494)	(0.0520)	(0.0427)
Trade block				0.322***	0.253***
				(0.0377)	(0.0287)
Intra-regional flights				0.647***	0.493***
				(0.0627)	(0.0505)
Landlocked				0.411***	0.124
				(0.134)	(0.0896)
Frequency (1–2 daily flights)					1.652***
					(0.0252)
Frequency (>2 daily flights)					2.391***
					(0.0450)
Constant	3.470***	6.735***	5.322***	0.945	1.789***
	(0.395)	(0.0661)	(0.412)	(0.615)	(0.472)
Observations	23,479	48,136	23,479	23,479	23,479
R-squared	0.122	0.114	0.167	0.186	0.374

Notes: Standard errors in parentheses (robust to heteroscedasticity and applying clusters at the route level). Statistically significant at 1% (***), 5% (**) and 10% (*). All regressions include year dummies.

distance and supply, as we have found in the analysis for belly cargo. In belly cargo, we find the expected negative relationship between supply and distance as it has been found in previous studies about passenger's flights. In dedicated cargo flights, the net effect from demand may be null because the deterrence effect of distance on trade may be compensated by the increased attractiveness of air in relation to other transport modes in longer routes. Note also that air freighters in dedicated cargo flights may not operate with high frequencies in short-haul routes to compete with ships and trucks.

Another striking difference is that the variable of low-cost airlines is negative and statistically significant in all regressions. Hence, it seems that low-cost airlines spur capacity in passenger flights, but they have a modest presence in cargo flights. The variable for network airlines operating in routes where the origin is a hub airport is not statistically significant, while the same variable when the hub is at the arrival is negative and statistically significant in most regressions. Thus, it seems that network airlines concentrate their capacity for passenger flights at their hubs, but such concentration does not arise for cargo flights. Note also that specialized freighters have a relevant role when considering dedicated cargo flights, which it may also explain the result for network and low-cost carriers.

It is also interesting to remark that the GDP per capita at the arrival is positive and statistically significant in all regressions, while results for the GDP per capita at the origin are mixed and always having a weaker effect than the former. Thus, the economic size of the arrival point matter in explaining the volume of freight tons in cargo flights, more clearly than it does for the capacity in passenger flights. In contrast, variables that are relevant for belly cargo like the HHI or the dummy for routes that link trading partners are generally not significant, or they are with a sign different than expected as it is the case for the dummy identifying landlocked countries.

Table 5 shows the results of the estimates of regressions that split the sample by different geographical areas. The dependent variable is the freight tons provided in all flights (belly cargo and cargo from dedicated flights). First, we consider the full sample, then we conduct estimates for sub-samples of extra-regional flights and intra-regional flights. Note that we focus from here on the results that consider all variables except frequency variables. The frequency variables distort the results for some other variables and their high correlation with the dependent variable suggest a potential problem of endogeneity. Results for most variables are similar regardless the subsample considered. However, the positive effect of the landlocked variable only holds in intra-regional routes and, surprisingly, the dummy variable for trade agreements is negative and statistically significant when we consider the sample of extra-regional flights. To this point, many trade agreements were signed long before the start of the period considered in this study, which could distort the identification of their effect.

Fig. 1 shows the coefficient estimates of the year dummy variables. These coefficients show the time trend once the rest of the explanatory variables have been controlled for. We consider regressions for belly cargo, cargo in dedicated flights, and total cargo in intra-regional and extra-regional routes. We find evidence of a negative time trend in the supply of belly cargo and total cargo in intra-regional flights since 2014. For extra-regional routes, the trend is generally more positive, especially in the years 2017–2019, though this suffered a reversal with the outbreak of the pandemic. The trend in cargo in dedicated flights is less clear, alternating positive and negative years, but it is clearly positive in the period from 2017 to 2020.

Table 4
Results of the estimates (dependent variable: cargo capacity – metric tons. Dedicated cargo flights).

VARIABLES	(1)	(2)	(3)	(4)	(5)
Distance	0.155***		0.0592	0.0515	0.0713*
	(0.0505)		(0.0440)	(0.0488)	(0.0416)
GDP_origin	0.111**		0.100**	0.0802	0.0769
	(0.0505)		(0.0456)	(0.0583)	(0.0571)
GDP_arrival	0.180***		0.172***	0.151***	0.129***
	(0.0474)		(0.0418)	(0.0506)	(0.0495)
Population_origin	0.161***		0.0872***	0.0873**	0.0678**
	(0.0398)		(0.0329)	(0.0343)	(0.0314)
Population_arrival	0.132***		0.0691**	0.0698**	0.0576*
	(0.0391)		(0.0327)	(0.0337)	(0.0308)
LCC_airlines		−1.750***	−1.095***	−1.106***	−1.124***
		(0.0879)	(0.200)	(0.202)	(0.199)
Network_airlines (hub_origin)		0.215	−0.179	−0.141	−0.378
		(0.409)	(0.400)	(0.388)	(0.318)
Network_airlines (hub_arrival)		−0.0875	−0.582**	−0.571**	−0.610**
		(0.210)	(0.247)	(0.244)	(0.247)
HHI		−0.471***	−0.161	−0.153	−0.152
		(0.0870)	(0.105)	(0.106)	(0.0997)
% wide-body flights		0.933***	0.736***	0.729***	0.749***
		(0.0615)	(0.0820)	(0.0866)	(0.0762)
Trade block				0.00606	−0.00722
				(0.0758)	(0.0658)
Intra-regional flights				−0.0837	−0.0517
				(0.111)	(0.107)
Landlocked				−0.751**	−0.679**
				(0.340)	(0.300)
Frequency (1–2 daily flights)					1.576***
					(0.0789)
Frequency (>2 daily flights)					2.845***
					(0.0907)
Constant	1.731***	7.632***	3.391***	3.869***	4.134***
	(0.666)	(0.0843)	(0.667)	(0.962)	(0.956)
Observations	3341	4615	3341	3341	3341
R-squared	0.166	0.197	0.242	0.244	0.311

Notes: Standard errors in parentheses (robust to heteroscedasticity and applying clusters at the route level). Statistically significant at 1% (***), 5% (**) and 10% (*). All regressions include year dummies.

Table 6 shows the regression results for the sample collapsed at the route level and not at the airline-route level and estimating a route fixed effects model. The purpose here is to analyze in more detail the role of free trade agreements and low-cost airlines. The fixed effects model exploits the within variation of the data, so that it focuses on the effect of changes in the variables of interest on provided tons. Hence, the trade block variable capture only those cases in which there have been changes during the period under consideration (that is, the agreement was signed after 2011). In a similar vein, the low-cost carriers variable capture only those cases in which any low-cost airline has provided services in the route after 2011. Additionally, the estimation by fixed effects also allows us to control for unobservable factors that do not vary over time.

Note that the multilateral agreements signed after 2011 include the free trade agreement of the EFTA states with Central America in 2014, the agreements of the European Union with the Andean Community in 2013 and with Central America in 2014 and the agreement Mexico signed with Central America in 2012. Several bilateral free trade agreements have also been signed since 2011.[10] Focusing on agreements signed after 2011 also has the advantage that it mitigates the potential problem of endogeneity arising from the fact that the agreements were signed between countries that already had a high degree of economic and commercial integration prior to that specific agreement. In this case, we can expect the free trade agreement to have been signed before 2011. Taking this into account, the results of the fixed effects model are in the same line as in the previous regressions. Thus, free trade agreements seem to contribute positively to a greater supply of air cargo, but this effect is concentrated on belly cargo and intra-regional routes.

Collapsing the data at the route level also allows us to examine in more detail how low-cost airlines affect freight traffic. In previous regressions, data was at the airline-route level so that a positive sign of the variable means that low-cost airlines are providing more capacity than other types of airlines. When looking at data at the route level with a fixed effects model, we can also identify whether the entry of low-cost airline in a route steal traffic from other airlines or generates additional traffic. In the passenger market, the empirical evidence suggests that the net effect on air traffic is positive (eg; Dresner et al., 1996; Graham and Dennis, 2010; Boonekamp et al., 2018; Calzada and Fageda, 2019). Given that belly cargo is strongly related with the passengers' market, we may expect that low-cost airlines spur belly cargo. In contrast, the presence of low-cost airlines in dedicated cargo flights is very modest in the period considered. In fact, there are not entries of low-cost airlines in dedicated cargo flights after 2011 in our sample of LAC countries. Thus, we cannot identify any effect of low-cost airlines in dedicated cargo flights.

Results of these regressions show that the entry of low-cost airlines promotes the increase of supply in air cargo services. The effect is positive and statistically significant when we consider the entire sample and the sample for belly cargo. It is also positive and statistically significant for extra-regional and intra-regional routes. While the overall effect of LCC seems to be positive, it is completely explained by the added capacity in belly cargo because there are no entries of LCC in dedicated

[10] There have been recent bilateral agreements between Chile and China, Hong Kong, Indonesia, Malaysia, Thailand, and Vietnam, between Colombia and United States and South Korea, Costa Rica with Singapore, Honduras with Canada and Panama with United States and Canada.

Table 5
Results of the estimates by geographical area (dependent variable: cargo capacity – metric tons. All flights).

VARIABLES	(1) All	(2) Extra-regional	(3) Intra-regional
Distance	−0.208***	−0.461***	−0.128***
	(0.0252)	(0.0533)	(0.0281)
GDP_origin	0.141***	0.144***	0.128**
	(0.0358)	(0.0549)	(0.0645)
GDP_arrival	0.119***	0.118**	0.0766
	(0.0355)	(0.0527)	(0.0724)
Population_origin	0.241***	0.242***	0.201***
	(0.0164)	(0.0253)	(0.0197)
Population_arrival	0.231***	0.255***	0.175***
	(0.0163)	(0.0244)	(0.0208)
LCC_airlines	0.432***	0.172**	0.669***
	(0.0346)	(0.0667)	(0.0460)
Network_airlines (hub_origin)	−0.0235	−0.0833	−0.105
	(0.0432)	(0.0616)	(0.0651)
Network_airlines (hub_arrival)	−0.00872	−0.0851	−0.0505
	(0.0454)	(0.0649)	(0.0655)
HHI	−0.539***	−0.324***	−0.887***
	(0.0608)	(0.0874)	(0.0752)
% wide-body flights	1.171***	1.388***	0.864***
	(0.0488)	(0.0680)	(0.0872)
Trade block	0.227***	−0.179***	0.401***
	(0.0377)	(0.0646)	(0.0414)
Intra-regional flights	0.515***		
	(0.0707)		
Landlocked	0.229*	−0.276	0.368**
	(0.131)	(0.233)	(0.161)
Constant	1.834***	3.478***	3.365***
	(0.646)	(1.115)	(0.682)
Observations	26,820	11,626	15,194
R-squared	0.214	0.265	0.222

Notes: Standard errors in parentheses (robust to heteroscedasticity and applying clusters at the route level). Statistically significant at 1% (***), 5% (**) and 10% (*). All regressions include year dummies.

cargo flights in the considered period. This does not necessarily mean that LCC harm this segment of the market. In fact, they may have started cargo operation businesses since the COVID-19 period.

Table 7 shows the results of the regressions that consider only those routes that have an airport in LAC as their point of origin. The purpose of these regressions is to analyze the role played by the quality of the infrastructure (at the point of origin of the route) in the supply of air cargo. Thus, we first consider regressions that include the infrastructure quality index as an additional explanatory variable. It should be borne in mind here that these regressions only consider the 30 departure airports for which such information is available. A positive effect of infrastructure quality is observed, although the effect is concentrated on extra-regional routes and cargo flights.

Similarly, the second set of regressions includes the total cargo provided at the departure airport (point of origin) as an additional explanatory variable. The coefficient of the variable is always positive and statistically significant, regardless of the sample considered. To the extent that we would expect a positive correlation between the size of the airport and the quality of the cargo-specific facilities, the results of the two variables point in the same direction although there is more heterogeneity in the effect when we focus on the infrastructure quality index.

Note that the variables of the quality of the infrastructure are not considered in the previous regressions due to data limitations. Indeed, data for these variables are only available for routes that have an airport in LAC as their point of origin. In the case of the infrastructure quality

Table 6
Results of the estimates with route fixed effects (dependent variable: cargo capacity – metric tons. All flights).

VARIABLES	(1) All	(2) Belly cargo	(3) Cargo flights	(4) Extra-regional	(5) Intra-regional
LCC_airlines	0.367***	0.413***	–	0.406***	0.333***
	(0.0367)	(0.040)		(0.0608)	(0.0437)
Trade block	0.410***	0.529***	−0.082	−0.321	1.007***
	(0.130)	(0.144)	(0.127)	(0.273)	(0.166)
Constant	23.56***	24.879***	23.327***	10.85***	42.68***
	(3.339)	(3.526)	(8.505)	(4.206)	(5.236)
Observations	30,061	26.690	3371	14,627	15,434
R-squared	0.101	0.106	0.095	0.163	0.087
Number of citypairs	6210	5872	717	2798	3412

Notes: Standard errors in parentheses (robust to heteroscedasticity and applying clusters at the route level). Statistically significant at 1% (***), 5% (**) and 10% (*). Only the results of low-cost airlines and trade agreements are reported although the regressions include the same variables as the regressions in column IV of Table 3.

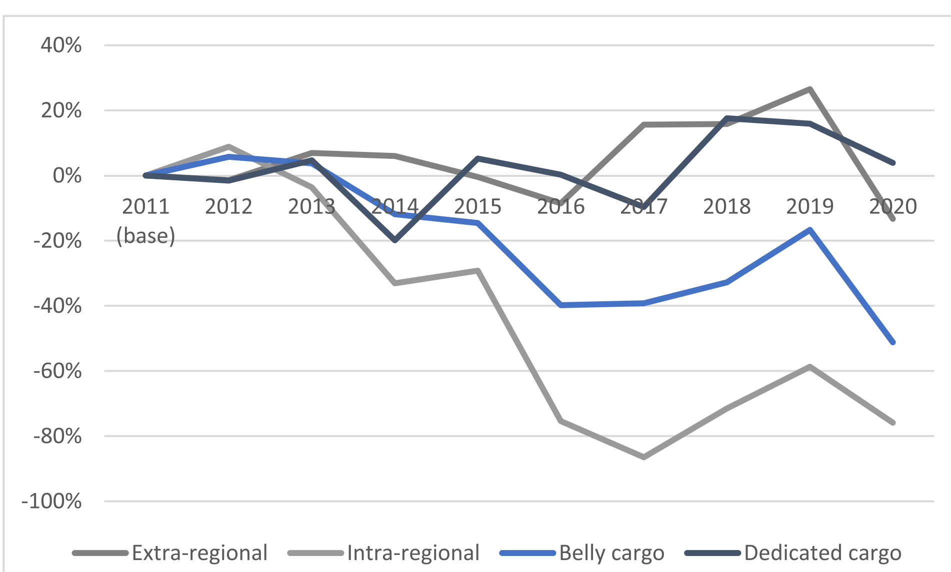

Fig. 1. Coefficient estimates of the year variables.

Table 7
Results of the estimates for infrastructure variables (dependent variable: cargo capacity – metric tons. All flights departing from airports in Latin America and the Caribbean).

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(5)	(6)
Infrastructure quality index	0.127 (0.145)	0.089 (0.151)	0.702** (0.340)	1.046*** (0.280)	−0.146 (0.179)					
Total cargo at departure airport						0.274*** (0.016)	0.259*** (0.016)	0.249*** (0.037)	0.311*** (0.0359)	0.280*** (0.0187)
Constant	3.021*** (0.714)	3.268*** (0.706)	2.480* (1.332)	6.725*** (2.249)	3.509*** (0.643)	1.073 (0.702)	0.409 (0.704)	2.915 (0.960)	3.489* (1.856)	1.782*** (0.657)
Observations	12,121	10,281	1840	3419	8702	20,955	18,424	2531	5761	15,194
R-squared	0.176	0.133	0.185	0.230	0.182	0.240	0.222	0.300	0.290	0.249
Sample	All	Belly cargo	Cargo flights	Extra-regional	Intra-regional	All	Belly cargo	Cargo flights	Extra-regional	Intra-regional

Notes: Standard errors in parentheses (robust to heteroscedasticity and applying clusters at the route level). Statistically significant at 1% (***), 5% (**) and 10% (*). Only the results of the cargo tons at the departure airport and the infrastructure quality index are reported although the regressions include the same variables as the regressions in Table 3.

index, the information is only available for a subset of airports.

5. Conclusions

Based on the analysis conducted here, we can infer several conclusions about the determinants of air cargo services supply. Given the values of the rest of the explanatory variables, the time trend is negative for belly cargo and intra-regional flights. As such, there has been a relative deterioration in intra-regional integration, at least in terms of air transport supply. That said, supply is higher on intra-regional routes than it is on extra-regional routes, indicating that integration in terms of air transport supply is greater between the countries of the region than it is with countries that lie outside the region. This result is driven by the belly cargo on passenger flights. The greater demand for passenger flights on intra-regional routes (and hence the higher supply on belly cargo services) could be explained by a greater degree of economic integration between LAC countries with the consequent greater tourist, commercial and migratory flows, as well as the existence of fewer regulatory obstacles to the supply of air transport services.

We find no evidence of a negative relationship between distance and air transport supply for dedicated cargo flights, as is typically reported in analyses of air passenger traffic. In dedicated cargo flights, the net effect from demand may be null because the deterrence effect of distance on trade may be compensated by the increased attractiveness of air in relation to other transport modes in longer routes.

Moreover, we also find evidence that weaker competition between airlines leads to lower cargo supply levels. One the one hand, this suggests that airlines compete in capacities. On the other hand, it can also be related with the fact that routes with less demand may also have lower competition. The implementation of proactive policies in support of competition could favor the development of air cargo insofar as limited competition may lead airlines to offer less supply. However, such policies should also consider that demand in some routes may be too low to make competition viable.

Additionally, we find evidence that trade agreements have a positive impact on the supply volume of air cargo, although this positive effect tends to be concentrated on belly cargo and intra-regional routes. Free trade agreements play an important role in the transport of goods by plane, suggesting that trade liberalization policies may have a certain relevance in promoting the economic integration of countries, which, in turn, can be further consolidated with the greater development of air cargo.

We also find evidence that the quality of infrastructure at the airport of origin positively impacts air cargo traffic, although the effect is concentrated on cargo in dedicated flights and extra-regional routes. The greater impact detected on extra-regional routes seems to be attributable to the greater complexity and sophistication of products exported to other regions. Whatever the case, however, investments in better infrastructure should benefit exports to other regions and promote better integration into global chains of production and distribution.

Our analysis also indicates that air cargo tends to concentrate in airports located in highly populated cities. This result is maintained regardless of whether we consider intra-regional or extra-regional flights, or whether we consider belly cargo or dedicated cargo flights. Investment in specialized cargo infrastructure at smaller airports might, therefore, help reduce the concentration of air cargo supply in the large airports of each country.

The results for the GDP variable are less clear than it should be expected. GDP at the arrival has a consistent positive impact on cargo in dedicated flights, while the effect of the income variable on belly cargo depends on the variables included in the model. Moreover, the results of the Granger causality analysis show that the relationship between GDP and air cargo is weak for most countries. Thus, the link between GDP and air cargo seems to be less apparent than that found in other studies made for richer regions or regions where air cargo is more developed. Thus, this relationship might become stronger over time.

Finally, we find evidence that low-cost airlines contribute to the increase of air cargo that is carried in the holds of passenger traffic. Low-cost airlines may stimulate demand (and supply) by offering lower fares although it could also be the case that they enter in high-density routes. In any case, this result suggests the existence of synergies between the market for passengers and that for cargo.

To conclude, some limitations of the analysis need to be mentioned. We have not been able to consider variables that approximate the costs of transporting cargo by plane or the degree of liberalization of the air market between the two countries. Our main indicator of the quality of the infrastructure is just for large airports and it is based on data of one year. In addition, results for some variables may be conditioned on the period and geographical area considered. A longer time span could lead to different results for the variable of free trade agreements in extra-regional routes. Finally, the low-cost market in LAC countries is underdeveloped with a remarkable presence in our dataset of low-cost airlines from United States and Europe that operate in dense markets. Further analysis on these issues may provide additional insights on the factors that stimulate or discourage the growth of air cargo supply, including a detailed analysis on the different types of products transported.

Author statement

All authors have worked together on: Conceptualization; Literature review; Data curation; Formal analysis; Investigation; Writing.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.tranpol.2023.03.009.

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