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Air cargo and economic growth in the Mexican states: 1992-2019

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Abstract

This article seeks to examine the causal relationship between air cargo and the economic activity of Mexican states. Analysis was conducted using Pedroni/Johansen cointegration tests, followed by Granger tests to analyze the long term and Wald tests for the short term, as well as an error correction model (VECM). The analysis was carried out for total cargo, which was then divided into domestic cargo on the one hand and international cargo on the other. The findings suggest the existence of long-term equilibrium and bidirectionality when total cargo is aggregated, although the causalities become unidirectional when cargo is disaggregated. These findings are then discussed in light of possible public policies.

Keywords: air transport; cargo; cointegration; error correction model (VECM).

1. INTRODUCTION

The effects of air travel on a country's economy have been researched all over the world with similar findings. The results obtained by Cruz and Rodríguez (2019), Koo *et al.* (2017) and Rodríguez-Brindis *et al.* (2015) are an example of this. Air cargo, however, receives less attention, despite globally representing less than 1% of the volume of goods being traded, which translates to 35% of the overall value traded (Sánchez and Weikert, 2020, p.15). Cargo being transported from a point of origin to a destination can have several consequences. The research presented here focuses on the economic growth at the state level in Mexico and focuses on air transport as the means used.

Despite the clear link between transport infrastructure and economic growth, the existing literature does not study the connection between the mode of transport used to ship cargo and economic growth in depth. This study aims to expand on the subject.

To define the subject as clearly as possible, the complementary nature of air transport and other means such as shipping by road, ultimately delivering the cargo to its destination, were not included. Given that each state's production structures varies, incoming or outgoing cargo from the airport can have a different aggregate value. This includes cargo being shipped to, or coming from, overseas. Heterogeneity is important when including the states dealt with in this study.

This article was divided into five sections to address the long-term relationship of air cargo and the national economy. Section one is the introduction, section two highlights the frame of reference used and offers a literature review. The third section describes the statistics used in the fourth section which deals with the empirical results of the econometric analysis put forward. This analysis emphasizes the long term in which the characterization of the fluctuations between the two variables is reviewed. Lastly, the fifth section presents the conclusions.

2. REFERENCE FRAMEWORK AND LITERATURE REVIEW

Three factors supporting the underlying reasoning used in this analysis, as well as a literature review of the subject, follow. The first focuses on the characteristics of air cargo and the variables that influence the sender's decision-making process when choosing this means of transportation.

Airplanes have technology that allow them to cover distances faster than other means of transportation, giving them an advantage over potential competitors. De Rus (2003) says that goods holders, those who decide the mode of transport used to send their cargo, have a flexible attitude towards time that is closely related to the value that the journey time represents for them. A merchandise that cannot spend too much time in transit could be highly sensitive to small changes in travel time. Goods sent by air, therefore, tend to have a high level of urgency with regards to delivery. The decision to send cargo by air is due to certain well-defined variables, according to the Mexican Institute of Transport (2005, p.5). Goods holders look for three factors when sending cargo by plane: how reliable[1] the service is, how competitive the rates are, and short transit times. Air travel fulfills this last requirement most successfully. The Economic Commission for Latin America and the Caribbean (The Economic Commission for Latin America and the Caribbean [CEPAL] 2017, p.3) indicates that this means of transportation is particularly important for shipments containing fish, fruit, perishables, fresh vegetables, and pharmaceutical products. Technological devices are another type of consignment that are usually shipped by air, as they have short life cycles and are sensitive to technological changes[2] (Mexican Institute of Transport, 2005, p.7). Mora (2014, p.33) points out that air transportation has other advantages, such as being competitive for large scale cargo. Other means of transport do not have a similar cargo capacity, and in addition the paperwork is easy, works under similar norms and is simplified in most countries. However, among the more obvious disadvantages are the inability to transport large volumes of liquids and minerals, higher costs than other modes of transportation, a tendency to suffer delays when the weather is not optimal and certain materials such as toxic or explosive residues not being suitable for shipping.

A second factor is associated to regional economic activity, as Isard (1971, p.40) says, data on the movement of people or goods is a reliable source for finding important connections or links between regions. The connection refers to a place of origin and a destination -where the cargo leaves from and where it arrives. The amount of cargo transported can be expressed in weight (kilos or tons), or monetary value. However, the importance of the relationship between origin-destination pairs can be conceived of as a hierarchy of the cargo's weight or value. This shows that the more value or weight that moves between origin-destination pairs, the greater the connection between the two of them is, and the less shipped, the less important. Important implications need to be highlighted here. First, the air cargo sent to a given destination is produced at the point of origin,[3] and forms part of the calculation of the economic activity there. Second, the destination will receive the cargo that will then be integrated into local economic activity, either as raw material that can be processed, or as final product that may not need to be processed but is still part of economic activity[4] .

A third important factor is the analysis timeline. In the transport economy, the relationship between transport infrastructure and mobile units is binding. The large investments made in the creation of infrastructure and its use are made expecting a long service life. Means of transport can have a shorter lifespan than the infrastructure used by them, depending, for example, on the technology employed -even then, durability can be medium term. This highlights the timeline in which this research study was carried out, as the constant use of infrastructure and the creation of new infrastructure are strongly linked to economic growth, as stated by Sanwei *et al.* (2021). It is important to note that a nearby airport is needed for cargo to have an impact on growth, which means that the airport itself boosts growth. Regions that do not have an airport will tend to have higher costs and longer transport times, for both outgoing and incoming cargo. In the case of Mexico, the influence of transport related infrastructure has been researched by Corrales and Mendoza (2021) and Noriega and Fontenla (2007). They found that the impact of infrastructure was a determining factor for growth. Moreover, the use of airport infrastructure reflects economic connections between two or more points and if they remain in use, the economic ties could be lasting.

The three factors mentioned above are interwoven in such a way that in the long term, the economic connections between two regions expressed by the weight or the value of the cargo shipped by air, are associated to economic activity both at the departure point and at the destination.

It is also important to emphasize that the empirical literature studying the relationship between air cargo and economic activity, generally measured by the Gross Domestic Product (GDP), diverges even though a distinction is made between studies using structurally econometric models and those that use time series, the latter being more common. López- Rodríguez and Pardo Rincón (2019) analyze the effects of importation and exportation on the Colombian and Ecuadorian economies. Chang and Chang (2009) researched the link between the growth of the GDP and air cargo in Taiwan in the long term and found that both variables are co-integrated, showing that air cargo is increasingly important for economic expansion. Chi and Baek (2013) obtained similar results and applied autoregressive distributed lag models to determine how much cargo demand tends to increase with economic growth, both in the short and long term. Evidence published by Mehmet (2019) shows that the relationship between cargo transport and the GDP is bidirectional and long -term. Md Mahbubul and Rico (2016) applied panel cointegration and Granger causality models for air cargo and the GDP for South Asian countries. They found that they are cointegrated and have a unidirectional relationship that runs from the GDP to freight transport.

There are studies that use indicators associated with cargo and passengers, such as the number of flights. One such is Shackman *et al.* (2021), that analyzes the relationship between four modes of transport, one of which is air, with other macroeconomic variables. The results show a cointegration relationship between all means of transportation. Simdi and Tunahan (2015) and Ghiorghe and Gianina (2013) are examples of other studies aiming to determine causal and cointegration relationships of transport with macroeconomic variables.

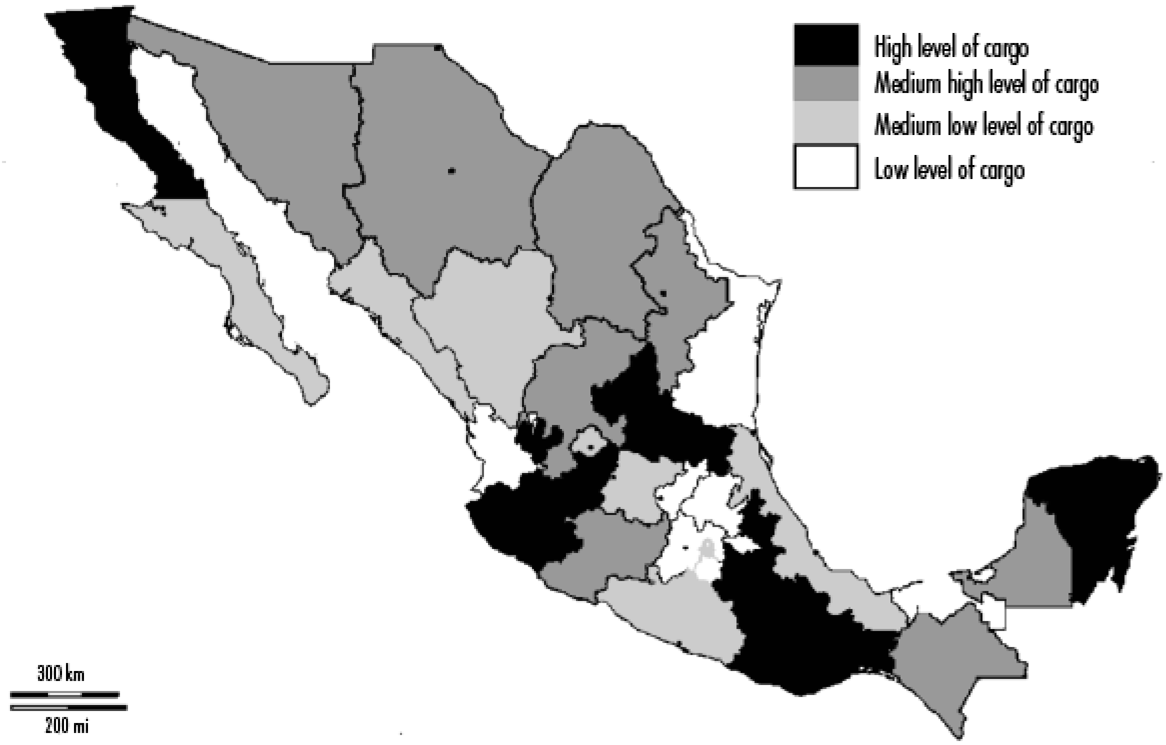
Heterogeneous results were found in the relationship between a macroeconomic variable with air transport, in terms of directionality. Chang and Chang (2009) found that Taiwan had a bidirectional causal relationship between economic activity and air transport. Baker *et al.* (2015) cites another bidirectional relationship, having analyzed national income and air traffic in Australia. Hakim and Merkert (2016) also reported findings of a bidirectional causality, using a sample of South Asian countries, between economic growth and volume of cargo as well as with passenger volume. Hu *et al.* (2015), studied 29 Chinese provinces and reported a bidirectional relationship between demand for flights and economic growth.

Brida *et al.* (2016), however, reported a unidirectional relationship running from transport to economic growth, when studying Italy. Fernandes and Rodrigues-Pacheco (2010) found a unidirectional relationship running from the GDP to air passenger transport in Brazil. Mukkala and Tervo (2013) also found unidirectionality running from aggregated economic activity to air traffic in the European Union.

Some Stylized Facts

At this point it is important to remember the established premise that the cargo was produced in the same area as it was shipped. In other words, the area where the airport is located, and the cargo's destination will be the locations for related economic activity. Cargo does not refer to passengers' luggage but raw materials or finished products. Data is reported monthly for each point of origin and destination (see figure 1) showing the average annual growth rate for cargo, with combined figures for domestic and international cargo[5] during 1992-2019. A total of cargo was calculated for areas that have several airports, as well as the monthly cargo, in order to calculate the annual figures exclusively for this graphic. As can be seen, the highest growth rates are in Quintana Roo with 4.1% and Baja California with 3.9%, whilst Tamaulipas has the lowest with 1.02%.

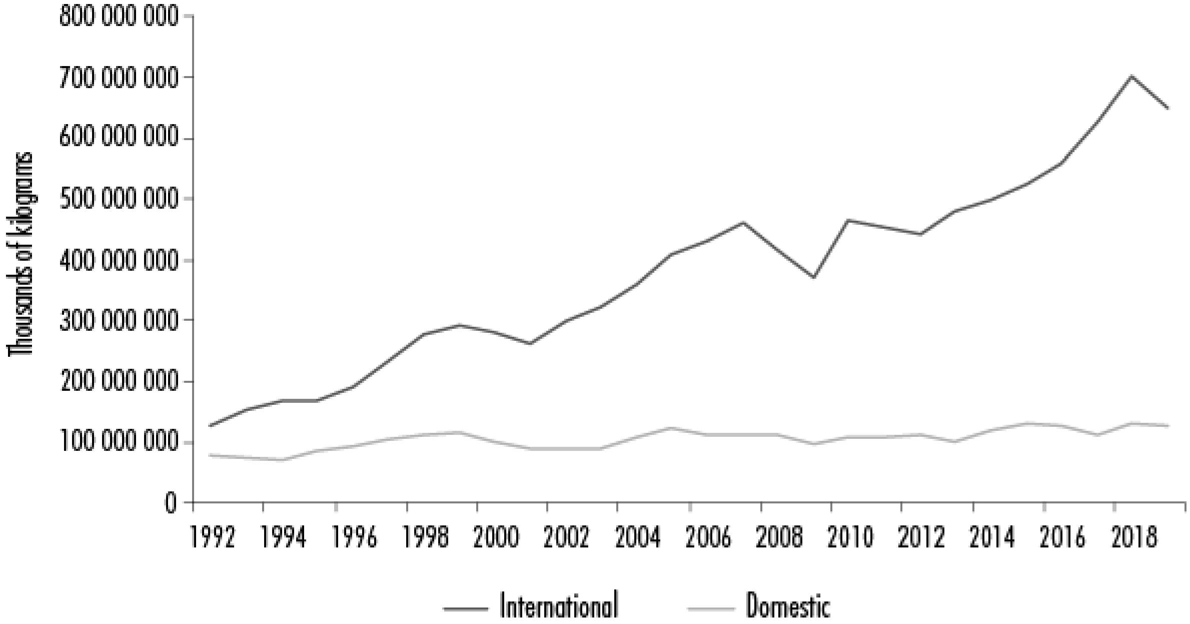
Figure 1. The average growth rate of total annual cargo 1992-2019



Source: created by the author using Secretariat of Communication and Transportation (SCT) data. Several years.

The annual evolution in thousands of kilograms, both for national and international cargo, has important differences. Cargo was added annually, and one can see that international cargo had a constant increase during the study period, whilst an increase in national cargo was barely visible (see figure 2). This was the basis for deciding to divide the study into two parts and observing the differentiated impact that national and international cargo can have on economic growth. International cargo had an average growth rate of 6.-7%, whilst domestic was 1.69%.

Figure 2. Total domestic and international cargo behavior 1992-2019 (thousands of tons)



Source: created by the author using Secretariat of Communication and Transportation (SCT) data. Several years.

3. DATABASE AND APPLICATION METHODS

This section's main objective is to study the long-term relationship between air cargo and economic growth. The aim is to determine the existence of such a relationship during the specified period and its causal direction.

A monthly data aggregate was used to calculate quarterly results from 1992 to 2019 for each airport, within its respective state. The variable is the cargo, expressed in thousands of kilos transported (KT). The National Institute of Statistics and Geography's (INEGI) Quarterly Index of State Economic Activity (ITAEE) was used as a proxy variable to the states' economic growth. Statistics on cargo were obtained from the Secretariat of Communication and Transportation (SCT). There are states such as Tlaxcala or Hidalgo that do not report having an airport and were therefore excluded from the study. Both KT and ITAEE were transformed into natural logarithms.

The causal analysis used is a standard econometric method in a panel data framework that seeks to prove cointegration and causality between KT and ITAEE. The causal relationship between these two variables could occur in one or two directions, or there could be no interdependent relationship. Thus, the aim is to discover whether the impacts of both types of cargo (domestic and international) are related to growth, separately. The analysis was carried out using Stata 12.2.

Not all states in Mexico have incoming or outgoing international cargo. The states with statistics reporting this type of cargo during the period analyzed were Aguascalientes, Baja California Sur, Mexico City, Chihuahua, Estado de México, Guerrero, Guanajuato, Jalisco, Nuevo León, Oaxaca, Quintana Roo, San Luis Potosí, Sinaloa, Sonora, Tabasco, Tamaulipas, Veracruz, Yucatán, and Zacatecas.

It is important to note that the Granger analysis uses three sequential steps to avoid reaching incorrect conclusions. First, it should be emphasized that, according to Baker *et al.* (2015, p. 143), the past variables of an *X* variable could be the result of the current behavior of a *Y* variable, but future *X* values cannot cause *Y*'s present values. However, the analysis applied can lead to incorrect results if the *X* and *Y* series are non-stationary. Given this, the first step was to apply stationarity tests to both KT and ITAEE. Then cointegration tests were applied to the series that had the same order of integration. The results obtained determined the causality test to be applied as a third step. If the series are cointegrated of order, then long-term parameters and causality are estimated using panel data, as well as an error correction model (VECM) finalizing with Granger causality Wald tests.

To begin the analysis, it is important to point out that a stationary process is one in which the average and the variable remain constant. If a variable is nonstationary, it can convert to stationary by obtaining the first difference of the nonstationary variable. In this case the number of times *d* is necessary to differentiate to make it stationary is said to be an integrated variable of order *d,* that is to say *I*(*d*). For this study, a stationary test for a data panel based on Im, Pesaran and Shin (hereon IPS) (2003) was used incorporating both temporal and cross section components. According to Baker *et al.* (2015) airports and their activity are heterogenous, meaning that the IPS test is acceptable. The expression of the equation is:

$$\Delta Y_{it} = \alpha_i \, Y_{it-1} + \textstyle\sum_{k=1}^{\rho} \; \beta_{ik} \, \Delta Y_{it-k} + X_{it} \, \delta_i + \varepsilon_{it} \qquad (1)$$

Where Y is the study variable, *i* = 1, 2, ..., N is the number of cross sections found in *t* = 1, 2, ..., N time periods. X is a regression vector that includes any fixed effect or even individual tendencies. ρ_i indicates the number of lags included, ε_{it} is the random disturbance and α_i is the error correction term. The null hypothesis is that each series in the panel does not have a stationary tendency, whilst the alternative shows that at least one is stationary. α_i is the error correction term. If $|\alpha_i| < 1$ the series is stationary but if $|\alpha_i| \geq 1$ the series has a unit root and is, therefore, nonstationary.

The Pedroni panel cointegration test (1999) was then used. According to Hakim and Merket (2016) this test allows for the capture of heterogeneous tendencies in the cross-sectional data. This is an important characteristic because not calculating the heterogeneity of the regression parameters when they exist, could lead to changes in the cointegration relationship between the dependent variable and the regressors leading to biased results. According to Cruz and Rodríguez (2019, p.13), Pedroni tests (1999) are based on the analysis of the stationarity of the panel residues in which the relating variables are I (1). The test is expressed as:

$$LnKT_{it} = \alpha_i + \delta_{it} + \beta_{1i}\, LnITAEE_{it} + \varepsilon_{it} \qquad (2)$$

Where i = 1,.., N is each state, t =1,….,T is the time period. KT_{it} is the cargo in miles transported by air. $ITAEE_{it}$ is the proxy for economic growth for each state *i* in the year *t.* The parameters α_l and δ_{it} allow for the possibility of fixed effects between states and deterministic trends, respectively. The estimated residues are deviations from the long-term relationship, $\varepsilon_{it.}$ The null hypothesis is non-cointegration and as such the residuals from equation 2 have a unit root, while the alternative shows that such residuals are stationary at levels for which the following regression is used:

$$\varepsilon_{it} = \rho_i\, \varepsilon_{it-1} + \mu_{it} \qquad (3)$$

In this respect, Pedroni (1999) proposed two cointegration test groups that use a total of seven test statistics. The first group is based on the Phillips and Ouliaris (1990) tests statistic, that proposes homogeneity in the cross-sections. The second includes statistics that allow for heterogeneity in the cross sections and groups the residuals in a panel (Campos, 2012). For this research article, the second group of tests will be used, (between dimensions), which in turn includes three statistics (Rho, PP, and ADF), as this group takes into account the heterogeneity that could occur between cross sections.

According to Baker *et al.* (2015, p.145), to find cointegration, the bivariate criterion is restrictive and only applicable for a cointegration relationship. The most common method is that of

Johansen and Juselius (1990), which defines the number of cointegration equations and offers two tests: trace statistics and maximum eigenvalue.

According to Belloumi (2009), if the cointegration test indicates that the two series (KT and ITAEE) are cointegrated, the possibility of a spurious correlation is ruled out. The cointegration means that causality exists between the two variables in the long term but does not show their direction for which the VECM is used. This has the advantage of distinguishing the long term from the short term and allows for the sources of causation to be recognized. Thus, Engel and Granger (1987) showed that if two series are cointegrated, the VECM obtained by using KT and ITAEE) can be expressed as:

$$\Delta \mathbf{LnITAEE}_{it} = \alpha_{it} + \beta_{it}\, \mathrm{ETC}_{it-1} + \sum_{i=1}^{\rho} \gamma_{it} \Delta \mathbf{LnITAEE}_{it-1} + \sum_{i=1}^{\rho} \delta it \Delta \mathbf{LnKT}_{it-1} + \varepsilon_{it} \tag{4}$$

$$\Delta \mathbf{LnKT}_{it} = \alpha_{it} + \beta_{it}\, \mathrm{ETC}_{it-1} + \sum_{i=1}^{\rho} \gamma_{it} \Delta \mathbf{LnKT}_{it-1} + \sum_{i=1}^{\rho} \delta it \Delta \mathrm{LnITAEE}_{it-1} + \varepsilon_{it} \tag{5}$$

Where Δ is the operator that expresses first differences. LnITAEE and ΔLnKT express a natural logarithm of ITAEE and KT, respectively in the i = 1, 2,….N states in the t = 1, 2, …..T periods of time, ε_{it} is an error term that it is hoped is white noise, ρ indicates the lag extension and $ECTi_{t-1}$ is the error correction term that is the result of the cointegration result, and evaluates the level of imbalance in the past.

The β_{it} coefficients from equations 4 and 5 allow the long-term directionality of the causal relationship to be evaluated. Using these parameters, the adjustment speed to reestablish balance can be calculated.

Equation 4 means that if the information contained in the past values of ΔKT is significant for explaining ΔITAEE with its past values and with each state's specific effects, then we can say that ΔKT Granger causes ΔITAEE. Thus, a change in the KT level can lead to a change in the ITAEE. The same can be interpreted in equation 5, as the information contained in the past values of ΔITAEE is significant in explaining ΔKT along with its past values and the specific effects of the airports controlled for. We can then say that ΔITAEE Granger causes ΔKT. According to Baker *et al* (2015, p.145) this situation becomes fundamental as the determinant variables for economic growth need to be specified to identify the air cargo effect. Such determinants can be unobservable or difficult to measure on time lags. Moreover, in each of the equations, the endogenous variable is caused by the previous level of imbalance ($ECTi_{t-i}$).

Three different causal relationships are evaluated: long-term, short-term and the Granger causality test, which will be explained below. In the short-term it is possible to calculate causality using VECM, as the coefficients estimated based on the first lag differences associated to the independent variables that correspond to the δ_{it} term in equations 4 and 5 show how dependent variables relate to independent variables in the short term. Therefore, the standard Wald test evaluating the combined significance of the aforementioned coefficients is applied so that if the lags are significant, the dependent variable will show causality in the short term with the explanatory variable.

In so far as the long-term, the variables' directionality can be determined from coefficients β_{it} (ECT) as well as quantifying speed adjustment in relation to long-term equilibrium. ECT is the lag error term for a time period. Long-term causality can be confirmed when the estimated coefficient is negative, significant and has values between 0 and 1, even though the absolute value indicates the speed with which equilibrium is restored. The Granger causality, however, explores the combined significance of the short- and long-term coefficients (δ_{it} and β_{it}) of the corresponding equations. This allows panel heterogeneity to be sufficiently analyzed by contrasting the joined hypothesis $\delta = 0$ and $\beta = 0$ for all of *i.* This test specifies if the lag factors act as a motor for reestablishing equilibrium in the long term (Cruz and Rodríguez, 2019, p. 15)

4. EMPIRICAL RESULTS

First, an IPS test was applied to determine the order of integration of variables. The results indicate that the series are non-stationary at level, therefore a first difference was applied showing that all the series are I (1) (see table 1).

Table 1. Results of the unit root test

Variable		IPS (Im, Pesaran and Shin)	
		Level	*First difference*
The total sample			
LnITAEE	Intercepto		-19.3410**
	Intercepto y tendencia	0.7701	-16.7125**
LnKT	Intercepto		-18.3374**
	Intercepto y tendencia	-0.3344	-17.8647**
Domestic Freight			
LnITAEE	Intercepto	-1.8066	-22.9514**
	Intercepto y tendencia	-2.3022**	-19.6564**
LnKT	Intercepto	-0.6633	-16.0820**
	Intercepto y tendencia	1.7154	-21.1537**
International Freight			
LnITAEE	Intercepto	-1.0831	-20.1001**
	Intercepto y tendencia	0.2510	-16.6163**
LnKT	Intercepto	-1.7008	-17.3917**
	Intercepto y tendencia	-0.3327	-22.3710**

Note: **$p < 0.05$.

Source: created by the author using data from the Secretariat of Communication and Transportation (SCT) and The National Institute of Statistics and Geography's (INEGI). Several years.

Once the order of integration of variables was calculated, Pedroni and Johansen cointegration tests were applied and the results found are shown in tables 2 and 3. The long-term equilibrium relationship between cargo transported by air and economic growth was confirmed by both tests.

Table 2. Pedroni cointegration test results

	LnITAEE and LnPAS
The total sample	
Rho Statistical Group	-5.9198**
PP Statistical Group	-4.0007**
ADF Statistical Test	0.9611
Domestic Cargo	
Rho Statistical Group	-7.4736**
PP Statistical Group	-6.312**
ADF Statistical Test	1.3588
International Cargo	
Rho Statistical Group	-3.7725**
PP Statistical Group	-3.0108**
ADF Statistical Test	1.713

Note: **$p < 0.05$.

Source: created by the author using data from the Secretariat of Communication and Transportation (SCT) and The National Institute of Statistics and Geography's (INEGI). Several years.

Table 3. Johansen cointegration test

	Trace	*Maximum Eigenvalue*
The total sample		
None	86.44**	88.50**
At least one	73.79**	73.79**
Domestic cargo		
None	68.60**	63.02**
At least one	56.48**	56.48**
International cargo		
None	45.26**	43.93**
At least one	39.89**	39.89**

Note: $^{**}p < 0.05$.

Source: created by the author using data from the Secretariat of Communication and Transportation (SCT) and The National Institute of Statistics and Geography's (INEGI). Several years.

The VECM was then calculated and was used to determine the direction of causality (results shown in tables 4, 5, and 6). The criterion established by Holts-Eakin *et al*. (1998) indicating that the number of lags must be lower than a third of the time used on the sample, was used to select the number of lags.

The Hurlin (2004) criterion indicates that the calculation of the lag numbers must be based on $T_i > 5 + 2K$ (where T_i refers to time passed and K to number of lags). For this study, seven lags were used that satisfied both criteria. This number is based on the information criterion of Akaike (AIC) and Schwarz (SIC) respectively.

The VECM calculates long-term direction of causality and specifies the adjustment speed obtained with the estimation of β in equations 4 and 5. Similarly, the VECM contains a certain number of lags with which the effect on short term dependent variables can be observed.

Table 4 shows the VECM results for national and international cargo aggregation. In the first model, the variable for freight transported (KT) is dependent and the proxy for growth (ITAEE) is independent. This model seeks to discover if the lag values for growth influence cargo.

Table 4. VECM aggregated cargo results

Explanatory factors	*Model 1* ΔLnKT	*Explanatory factors*	*Model 2* ΔLnITAEE
1st quarter lag ΔLnITAEE	0.2836**	1st quarter lag ΔLnKT	0.4308*
2nd quarter lag ΔLnITAEE	0.2383**	2nd quarter lag ΔLnKT	-0.0089
3rd quarter lag ΔLnITAEE	0.0030	3rd quarter lag ΔLnKT	-0.0046
4th quarter lag ΔLnITAEE	-0.0074	4th quarter lag ΔLnKT	0.1092*
5th quarter lag ΔLnITAEE	0.0258**	5th quarter lag ΔLnKT	0.0022***
6th quarter lag ΔLnITAEE	-0.1307	6th quarter lag ΔLnKT	0.0401
7th quarter lag ΔLnITAEE	0.0160	7th quarter lag ΔLnKT	0.0063
Long term causality (ECT)	**-0.1041****	Long term causality (ECT)	**-0.0863****
Constant	-0.1689*	Constant	-0.0371**
R squared	0.5241	R squared	0.4102
R squared adjusted	0.5156	R squared adjusted	0.4076
Log Likelihood	875.3100	Log Likelihood	981.2400
F statistic	47.05800	F statistic	43.73400

Notes: *$p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.
Source: created by author.

The ECT coefficient (β_{it}) is negative, significant and within the range of values expected and indicates that cargo produces adjustment effects in the long term on economic growth. This result shows that there is a direction in causality, from economic growth to the freight transported. The coefficient value indicates that approximately 10.4% of nonequilibrium is corrected in a quarter.

There are also short-term effects; 1, 2 and 5 lags have positive impacts on the volume of cargo transported. A possible explanation is that economic growth can take a while to impact on the demand for cargo due to some variables, income being one of them. With regards to size, it is understandable that an increase in economic growth leads to a 0.28% increase in cargo transported during the first quarter and a 0.23% increase in the second. The second model has economic growth as a dependent variable and lags in freight transported, as an independent variable. β_{it}'s value is significant and the speed of adjustment shown is 8%, which is approximately the nonequilibrium value corrected in the short term.

The lags in model 2 show an immediate positive impact of freight transported to growth. This indicates that a one-unit percentage increase in freight creates an increase 0.43% on economic growth after one quarter.

The results obtained from models 1 and 2 suggest the presence of a bidirectional causal relationship as both coefficients (ECT) are significant and have the expected values; the transported cargo causes economic growth and economic growth causes transported cargo.

Table 5 shows the VECM estimation results, with regards to international cargo and is divided into two models. The case for model 3 shows that the coefficient that represents ECT is not significant as it indicates that there is no long-term causal relationship between economic growth and cargo traffic. There are impacts in the short term as there are significant lags, but model 4 is significant and its magnitude is as expected. This indicates a unidirectional relationship in the long term, running from the transported cargo to economic activity with an adjustment speed of almost 3% and with short-term impacts, as the lags from the first quarters are significant.

Table 5. VECM results for international cargo

Explanatory factors	*Model 3* ΔLnKT	*Explanatory factors*	*Model 4* ΔLnITAEE
1st quarter lag ΔLnITAEE	0.3016**	1st quarter lag ΔLnKT	0.2357**
2nd quarter lag ΔLnITAEE	0.0222	2nd quarter lag ΔLnKT	0.0050**
3rd quarter lag ΔLnITAEE	0.0152	3rd quarter lag ΔLnKT	-0.0090
4th quarter lag ΔLnITAEE	-0.0240	4th quarter lag ΔLnKT	-0.0419
5th quarter lag ΔLnITAEE	-0.1170	5th quarter lag ΔLnKT	0.0890***
6th quarter lag ΔLnITAEE	-0.0337***	6th quarter lag ΔLnKT	-0.0368
7th quarter lag ΔLnITAEE	-0.1212	7th quarter lag ΔLnKT	-0.0090
Long term causality (ECT)	0.0003	Long term causality (ECT)	**-0.0299*****
Constant	0.2819	Constant	1.2728**
R squared	0.3909	R squared	0.4390
R squared adjusted	0.3912	R squared adjusted	0.4208
Log Likelihood	88.7310	Log Likelihood	70.5706
F statistic	31.0080	F statistic	26.3309

Notes: *$p < 0.10$; **$p < 0.05$; ***$p < 0.01$.
Source: created by author.

Table 6 contains the VECM estimate for domestic cargo, divided into two models. Model 5 presents evidence of the existence of a long-term unidirectional relationship running from economic activity to cargo transported. The estimated coefficient is significant and has the expected values, indicating an adjustment speed of 7.3%. In the short-term there is evidence of a positive impact on the lags estimated. Lastly, model 6 shows no evidence of a long-term causal relationship as the estimated coefficient is not statistically significant.

Table 6: VECM results for domestic cargo

Explanatory factors	*Model 5* ΔLnKT	*Explanatory factors*	*Model 6* ΔLnITAEE
1st quarter lag ΔLnITAEE	0.0260	1st quarter lag ΔLnKT	0.1419*
2nd quarter lag ΔLnITAEE	0.0961***	2nd quarter lag ΔLnKT	0.0007
3rd quarter lag ΔLnITAEE	0.0640***	3rd quarter lag ΔLnKT	-0.0099
4th quarter lag ΔLnITAEE	-0.2273	4th quarter lag ΔLnKT	0.1564
5th quarter lag ΔLnITAEE	0.0170***	5th quarter lag ΔLnKT	-0.5836
6th quarter lag ΔLnITAEE	-0.2163	6th quarter lag ΔLnKT	-0.0292*
7th quarter lag ΔLnITAEE	-0.0460	7th quarter lag ΔLnKT	-0.0360
Long term causality (ECT)	-0.0730***	Long term causality (ECT)	0.0904
Constant	-2.4163	Constant	3.9848*
R squared	0.2875	R squared	0.1436
R squared adjusted	0.2694	R squared adjusted	0.1327
Log Likelihood	112.4000	Log Likelihood	90.0020
F statistic	9.7717	F statistic	12.3382

Notes: *p < 0.10; **p< 0.05; ***p < 0.01.
Source: created by author.

The first two models' results estimated indicate that, when both national and international cargo are aggregated there are long-term bidirectional causal relationships. However, when they are disaggregated into international and national cargo, the results change. With regards to international cargo, a unidirectional relationship was found running from transported cargo to economic growth. This can be interpreted in the following manner: international cargo is classified as coming from abroad and is integrated into the national economy and stimulates it. The same can be said for cargo leaving the country to an international destination. For example, exportation is clearly associated to the economic growth of the Mexican states studied.

National cargo has a long-term unidirectional relationship that runs from economic growth to transported cargo. This suggests that the intermodal percentages used for air cargo are not sufficient to stimulate economic growth. Growth, however, stimulates air transportation.

Table 7 summarizes the results of the three tests undertaken to analyze the directionality between economic growth and cargo transported by air. The first test (short-term causality) shows a Chi-Squared test statistic that is significant to 5%, for only three out of a total of six cases. When the entire sample is used, the results indicate a causal bidirectional direction between the variables of interest. Thus, in the short term, the increase of the total of cargo transported leads to an increase in economic activity and, simultaneously, economic growth fuels cargo transported by air. When only analyzing domestic cargo transportation, the results cannot confirm either of the two directions. However, in the case of international cargo, the direction running from cargo to economic growth is significant, but not in the opposite direction.

Table 7. Summary of causality and direction results

Series	*Variables*	*Short-term Wald*	*Long-term ECT*	*Granger Causality*
The entire sample	ITAEE → KT	32.4**	-0.1041**	26.31**
	KT → ITAEE	19.07**	-0.0863**	78.09**
Domestic cargo	ITAEE → KT	0.487	-0.073**	10.28
	KT → ITAEE	3.55	0.0904	4.77
International cargo	ITAEE → KT	2.77	0.0003	1.83
	KT → ITAEE	22.46**	-0.0299**	55.02**

Note: **$p < 0.05$.

Source: created by the author using data from the Secretariat of Communication and Transportation (SCT) and The National Institute of Statistics and Geography's (INEGI). Several years.

The Granger Causality Test shows statistical significance to 5% for the total sample as well as for international cargo, which implies a causal bidirectional relationship. Only a unidirectional relationship running from cargo to economic growth can be seen for domestic cargo

In the long-term analysis, the VECM estimated coefficients are significant in both directions, when looking at the total sample. Thus, for total long-term cargo, the causality is bidirectional between air cargo and economic activity. The coefficients' value indicates that the increase in economic activity boosts air cargo by 10.4% and that air cargo promotes growth of around 8.6%. However, when one focuses exclusively on domestic air cargo, the causal relationship is unidirectional and runs from economic growth to air cargo. Finally, international cargo indicates a unidirectional causal relationship that runs from the cargo transported to economic growth.

The results are highly heterogeneous, however, when bidirectionality is added to total cargo, as the cargo transported is shown to incentivizes growth. This occurs both where it is loaded (origin) and where it arrives (destination), as it will be part of economic activity. Similarly, production at the point of origin incentivizes air cargo, as a part of it will be sent by air to other parts of the country or the world. Domestic cargo has a smaller impact on economic activity than international cargo (see figure2) and registers less weight, indicating lesser importance.

One possible explanation of the fact that international cargo fosters economic growth could be that different production exists in each state, as there are states in which the cargo that arrives or leaves can have a high component of aggregated value. Similarly, cargo being sent abroad is differentiated in each state, as some states will require raw materials with a high aggregated value or technology, and others will require merchandise for final consumption of products that may not be as high in value.

5. CONCLUSIONS AND RECOMMENDATIONS

The primary objective of this study was to analyze the long-term relationship between air cargo and economic growth at state level in Mexico from 1992 to 2019. Three causality tests that are often cited and used in the literature reviewed, were applied. These were short-term, long-term and Granger causality. The total sample was divided into domestic cargo and international cargo, given that the statistics review showed that each category displayed significant behavioral differentiation. International cargo showed a constant increase during the period studied whereas national cargo, only a slight increase. Total cargo showed the existence of a bidirectional causal relationship. However, on dividing the cargo into two categories, disaggregation was found to impact on the direction of causality, for international cargo has a unidirectional relationship impacting on the economic growth of the states included in the study, whereas national cargo is influenced by economic growth but is unidirectional, (possibly due to lower cargo volumes.)

There is a pattern in connection with cargo aggregation, as the short-term and Granger causality tests are significant. The three tests are only significant in the case of international cargo when analyzing directionality running from cargo to economic growth. In all other cases, the three tests were not reported to be significant.

Public policy recommendations, based on the results obtained, focus firstly on the bidirectionality found. Bidirectionality clearly incentivizes all types of cargo, whether going to or leaving a state, as it stimulates growth. Economic growth, in turn, stimulates air cargo transportation, generating benefits in various economic sectors. Incentives for using air cargo could take the shape of making investments to improve airports and complementary services, as well as in other modes of transport. The unidirectionality found for national cargo leads to the recommendation that airports should remain operational, allowing economic growth to sustain these in the long run. In the case of international cargo, actions are needed that generate an increase in cargo to stimulate growth.

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[1] Reliability refers to fulfilling security and customs regulations when dealing with international cargo.

[2] Courier services also ship this way as the sender usually needs their package (often paperwork) to arrive at the destination speedily, making air cargo a good choice for this type of cargo.

[3] The premise that the cargo was produced in the same state as the airplane was loaded is established. There could be cases of the shipment being produced in a different state than that of the airport used to load the merchandise, but there is not enough data to quantify this scenario. Similarly, the premise that the cargo will be used for economic activity at the destination, is made.

[4] It is important to mention that air cargo generates a certain amount of revenue for other economic sectors, such as payment of airport taxes and other specialized services- refrigeration or specialized machinery for dealing with cargo such as forklift trucks are two examples.

[5] The terms national and international cargo were used as follows; national cargo is used when statistics show that the point of origin and destination are national, whilst international cargo is understood to mean that one of the two areas is abroad (either point of origin or destination).