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TESTING LINEARITY IN THE LONG-RUN RELATIONSHIP BETWEEN ECONOMIC GROWTH AND PASSENGER AIR TRANSPORT IN MEXICO

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Abstract: This paper analyzes the dynamic relationship between Mexican air transport expansion and economic growth. To this end, non-parametric cointegration techniques and non-parametric causality tests are introduced and applied to quarterly data of GDP and number of air passengers in Mexico for the period 1995-2013. These procedures allow to test the existence of long run relationship between the variables and to decide whether the model is linear or not. The empirical results show the existence of a cointegration relationship between air transport and economic growth, and that this relationship is linear. In addition, the nonparametric causality tests confirm bidirectional causality between transport and growth.

Keywords: air transport and growth, nonlinear co-integration; non-parametric causality tests; Mexico.

jel Classification: C30; E43; L83

1. Introduction

Air transport is a strategic factor that can play a key role in facilitating economic development, particularly in developing countries and in enhancing long-term economic growth. Conversely, the economic growth of a country can also have

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significant effects on air transport expansion. Air transport activity may impact through different channels on economic growth. First, air transport is a significant foreign exchange source (Van de Vijver et al., 2014). Second, air transport has an important role in stimulating investments in new infrastructure. Third, given the complex mix of transport-related sectors air transport stimulates other economic industries by direct, indirect and induced effects. Fourth, air transport contributes to the generation of employment and the rise in incomes (Özcan, 2013). Fifth, air transport causes positive economies of scale, helping to boost a country's competitiveness, and finally, air transport is an important factor in the diffusion of technical knowledge. Conversely, economic growth can also have significant effects on air transport expansion. For example, by the development of the hard infrastructure such as airports which give the opportunity to promote export activities including tourism, enhance business operations and productivity and influence company location and investment decisions (Halpernand Bråthen, 2011).

International literature that account about linkages between air transport demand and economic growth emerged recently and is still scarce (Green, 2007). Chang and Chang (2009) analyze the relationship between air cargo expansion and economic growth in Taiwan. Their results indicate that air cargo traffic and economic growths are co-integrated showing that in the short and in the long run there is a bi-directional causality. For Brazil, Fernandes et al. (2010; 2014) and Marazzo et al. (2010) found a co-integration relationship between air transport demand and economic growth and also a unidirectional equilibrium relationship between them. For US, Chi and Baek (2013) analyze both the short and long run relationships between economic growth and air transport in a different framework (an autoregressive distributed lag dynamic model). The study shows that in the long run, air passenger and cargo demand tends to increase with economic growth but on the contrary, in the short run, air passengers movements are negatively affected by some external shocks.

Mexico has an extensive airport system, actually counts with 1723 runaways and 85 airports, 29 of which are national and 56 international. The system carried 69 million passengers with 70% going through seven airports. Mexico City Airport (AICM) catered for 44% of the passengers and 58% of the cargo, benefits from the economic footprint of the industry (Ablanedo-Rosas y Gemoets 2010).

Air transport also has an important demand side contribution to Mexico's GDP through the value-added it creates. According to Oxford Economics (2011) in 2009, the aviation sector contributes MXN 50.2 billion (0.4%) to Mexican GDP. This total comprises: MXN 23.5 billion directly contributed through the output of the aviation sector (airlines, airports and ground services); MXN 15.4 billion indirectly contributed through the aviation sector's supply chain; and MXN 11.3 billion contributed through the spending by the employees of the aviation sector and its supply chain. Additionally, the industry supported 158.000 jobs (direct, indirect and induced) in Mexico. If we take account the "catalytic" impacts from tourism, the contribution raises to 2.0% of GDP, i.e. about MXN 233 billion (see Table 1).

Table 1. Aviation's contribution of output and Jobs to Mexico, 2010.

	Direct	Indirect	Induced	Total	% of whole economy
Contribution to GDP (MXN billion)					
Airlines	15.2	11.1	6.5	32.8	0.3%
Airports and Ground Services	8.3	4.3	4.8	17.4	0.1%
Total	**23.5**	**15.4**	**11.3**	**50.2**	**0.4%**
Catalytic (tourism)	99.5	45.9	37.4	182.8	1.5%
Total including catalytic	**123.0**	**61.3**	**48.7**	**233.0**	**2.0%**
Contribution to employment (000s)					
Airlines	24	41	24	89	0.2%
Airports and Ground Services	35	16	18	69	0.2%
Total	**60**	**57**	**42**	**158**	**0.4%**
Catalytic (tourism)	429	191	137	757	1.7%
Total including catalytic	**489**	**248**	**179**	**915**	**2.1%**

Source: Oxford Economics, 2011

In a recent paper (Brida et al, 2016) uses Johansen cointegration analysis (Johansen, 1988; 1995) and Granger Causality tests (Granger, 1981) to shows that air transport demand positively impacts Mexican economic growth. The elasticity of real GDP to air transport demand (0.56) shows that an increment of 100% in the number of air passengers in Mexico produces an increment of more than 50% of the real product. The study finds that there is a long-run equilibrium relationship between air transport industry and economic growth and that the causality between these variables is bi-directional. The paper also states that air transport activity in Mexico suffered some critical phenomena that might have affected significantly on this relationship.

The literature has analyzed in many ways and within different methodological outlines the relationship between tradable sectors and economic growth. Recent studies on Tourism-led growth hypothesis, developed within a nonlinear methodological framework (Brida et al, 2015) introduced a new perspective to address this issue. In fact, introducing the possibility that links between economic variables might be nonlinear doesn't imply deny that they could show -as it probably happens most of times- a linear pattern. On the contrary, it avoids restrict the empirical analysis (provided that economic theory does not impose limits), broadening the range of typologies of linkages between economic variables. In some cases, contrasting methods may lead to reject the nonlinearity hypothesis, but in others, not.

This work investigates the link between Mexican air transport and economic growth without imposing a priori any parametric model to represent this linkage. This is the first contribution differentiating this study with Brida et al (2016), where the relationship between the variables is estimated based on the strong hypothesis that the underlying model is linear, as is usual in this branch of the applied economics literature. Once confirmed the existence of a cointegration relationship between the variables a test to identify if the underlying model is linear or not is performed. Finally, once this point is clarified, the best specification can be estimated. In addition, this study introduces an alternative causality test and compares these results with those obtained in Brida et al (2016).

This study follows the methodology applied in Brida et al (2015), which adapts the methodology proposed in Ye Lim et al (2011). Specifically, we explore whether the development of transport sector improves economic growth, or if is the economic growth what gives impulse to air transport development, or, alternatively a bilateral influence takes place. We apply a set of "free-model" tests (unit root test, cointegration and causality non-parametric tests) to examine the existence of linear and nonlinear relationships between these variables and analyze the causality. Our results are compared with those obtained by using a traditional linear methodology. The analysis is applied to quarterly data of GDP and air passengers in Mexico for the period 1995-2013.

The structure of the paper is as follows. In the next section, the methodological econometric framework is introduced. Section 3 describes the data and section 4 gives the empirical results. Finally, main conclusions are presented in section 5.

2. Methodological framework

The methodological framework derives from a non parametric approach. Within this framework linear and nonlinear linkages between the variables can be tested. The definitions of linearity can be stated as follows. Consider a variable y_t depending on an explanatory vector z_t (including lagged y) related in the following form:

$$E(y_t/z_t) = \alpha' z_t + g(z_t) \tag{1}$$

Then the model is linear if and only if $g(z_t)$ (Lee et al, 1993).

Following Breitung (2001, 2002), Holmes and Hutton(1990) and Ye Lim et al (2011), the methodology for implementing nonparametric unit root test, cointegration test and Granger Causality test in a nonlinear framework are presented.

2. 1. *Nonparametric Unit Root Test*

Breitung (2002) constructs a statistic test that does not require the specification of the short run dynamic; such approach is called "model free" or "nonparametric" because the asymptotic properties of the test do not depend on the short run dynamics or the nuisance parameters. Then, the test is robust against a possible misspecification. Following Davison (2002), Breitung employs a definition of integration that is not restricted to a specific time series model.

A time series y_t is integrated of order one (I(1)) if, as $T \to \infty$,

$$T^{-1/2} y_{[aT]} \underset{T\to\infty}{\Longrightarrow} \sigma W(a) \tag{2}$$

where the symbol $\underset{T\to\infty}{\Longrightarrow}$ means weak convergence with respect to the associated probability measure, $\sigma>0$ is a constant, [.] represents the integer part, and W(a) is a Brownian motion defined on C[0,1].

Breitung (2002) proposes the variance ratio statistic to test the null hypothesis that y_t is I(1) against the alternative hypothesis y_t is I(0). Critical values are available in Breitung (2002).

The Q_T is the variance ratio of the partial sums and the original series, and variance ratio statistic is defined as:

$$\widehat{Q_T} = \frac{T^{-1}\sum_{t=1}^{T}\widehat{U}_t^2}{\sum_{t=1}^{T}\hat{u}_t^2} \tag{3}$$

where $\widehat{\mathrm{U}}_\mathrm{t} = \hat{\mathrm{u}}_1 + \cdots + \hat{\mathrm{u}}_\mathrm{t}$ and $\hat{\mathrm{u}}_\mathrm{t} = \mathrm{y}_\mathrm{t} - \hat{\delta}'\mathrm{z}_\mathrm{t}$ are the ordinary least square (OLS) residuals from the regression of the data y_t on (i) $\mathrm{z}_\mathrm{t} = 0$, let $\hat{\mathrm{u}} = \mathrm{y}_\mathrm{t}$, with no deterministic term, (ii) z_t=1, with an intercept, or (iii) z_t=(1,t)′, with an intercept and linear trend, respectively. The variance ratio statistic is a left tailed test, where the hypothesis of a unit root process is rejected if the test statistic value is smaller than the respective critical value.

2. 2. *Nonparametric cointegration test*

Since the introduction of the concept of cointegration by Granger (1981), the analysis was intense within a linear context, whereas the research within a nonlinear framework was less developed. Given two time series X_t and Y_t, both unit root processor that are cointegrated, in a linear context the attractor is defined by $Z_t = X_t\text{-}AY_t$, where Z_t is called by Granger (1995) the "short memory in mean". To generalize this context in a nonlinear context, it is assumed the attractor can be defined as a general function of the variables X_t and Y_t:

$$Z_t = g_1(X_t) - g_2(Y_t) \tag{4}$$

i.e., the short memory in mean is defined by a nonlinear combination of the variables.

Given that the economic theory not always provide a precise specification of the relationship between the variables, the use of nonparametric and/or non linear tools for estimation and inference is appropriate.

Breitung (2001) introduces a nonparametric test procedure based on ranks to test the hypothesis of a cointegration relationship (linear or not) and to identify whether this link is nonlinear. The idea of that residual based cointegration test (the rank test) is that the sequences of the ranked series tend to diverge if there is no cointegration between the variables. Breitung rank test checks whether the ranked series move together over time towards a linear or nonlinear long-term cointegrating equilibrium. The procedure starts checking the cointegration by using the rank test. If cointegration is accepted, the technique follows with examining linearity in the cointegration relationship, by using a scoring test.

As demonstrated by Granger and Hallman (1991), the Dickey-Fuller test may perform poorly when it is applied to a nonlinear transformation of a random walk. Authors as Phillips and Oularis (1990) analyze the effect of a nonlinear cointegration relationship on the power of a residual based cointegration test and proposed variant of the Dickey Fuller tests. Bretuing shows that residual based cointegration test supported on the statistics proposed by Phillips and Oularis (1990) is inconsistent for some kind of functions. The rank transformation of the time series tries to overcome these difficulties.

As in previous section, Bretuing applies Davidson's (2002) definition of integrated process.

Let $f(x_t)\sim I(1)$ and $g(y_t)\sim I(1)$ nonlinear increasing functions of x_t and y_t, and $\mu_t\sim I(0)$. Let suppose that a nonlinear cointegration relationship between x_t and y_t is given by

$$\mu_t = g(y_t) - f(x_t) \tag{5}$$

The rank statistic is constructed by replacing $f(x_t)$ and $g(y_t)$ by the ranked series

$$R_T[f(x_t)] = R_T(x_t) \tag{6}$$

and

$$R_T[g(y_t)] = R_T(y_t) \tag{7}$$

Given that the sequence of ranks is invariant under monotonic transformations of the variables, if x_t or y_t are random walk process then $R_T[f(x_t)]$ and $R_T[g(y_t)]$ behaves like the ranked random walks as $R_T(x_t)$ and $R_T(y_t)$. The rank test procedure is based on two "distance measures" between the sequences of $R_T(x_t)$ and $R_T(y_t)$.

The cointegration test is based on the difference between the sequences on the ranks can be detected by the bivariate statistics K_T^*: and ξ_T^*,

$$K_T^* = T^{-1}\max_t|d_t|/\hat{\sigma}_{\Delta d} \tag{8}$$

$$\xi_T^* = T^{-3}\sum_{t=1}^{T} d_t^2/\hat{\sigma}_{\Delta d}^2, \tag{9}$$

where

$$d_t = R_T(y_t) - R_T(x_t), \tag{10}$$

for $R_T(y_t)$ = Rank [of y_t among y_1, ... y_T] and $R_T(x_t)$ = Rank [of x_t among x_1, ... x_T].

The $\max_t|d_t|$ is the maximum value of $|d_t|$ over t=1,2, …, T and

$$\widehat{\sigma}^2_{\Delta d} = T^{-2} \sum_{t=2}^{T} (d_t - d_{t-1})^2 \tag{11}$$

adjust for possible correlation between the series of interest.

Furthermore, it is possible to generalize the test to cointegration among k+1 variables y_t, x_{1T}, …, x_{kt}, where it is assumed that $g(y_t)$ and $f(x_{jt})$ are monotonic functions.

Let $R_T(x_t) = [R_T(x_{1T}), …, R_T(x_{kT})]'$ be a *(kx1)* vector and $\tilde{b}_T$ the OLS estimation from a regression of $R_T(y_t)$ on $R_T(x_t)$. Using the residuals:

$$\tilde{u}^R_t = R_T(y_t) - \tilde{b}'_T R_T(x_t) \tag{12}$$

a modified multivariate rank statistic is obtained from the normalized sum of squares:

$$\Xi^*_T[k] = T^{-3} \sum_{t=1}^{T} (\tilde{u}^R_t)^2 / \widehat{\sigma}^2_{\Delta\tilde{u}} \tag{13}$$

where

$$\widehat{\sigma}^2_{\Delta\tilde{u}} = T^{-2} \sum_{t=2}^{T} (\tilde{u}^R_t - \tilde{u}^R_{t-1})^2 \tag{14}$$

accounts for a possible correlation between the series.

The null hypothesis of no cointegration is rejected if the test statistic is below the respective critical value (Breitung 2001).

2. 3. *Rank test for neglected nonlinearity*

If cointegration exists in the first step, then we proceed to examine the linearity of the cointegration relationship.

For a convenient representation of the alternative and null hypothesis Bretuing (2002) follows Granger (1995) and represents the nonlinear relationship as:

$$y_t = \gamma_0 + \gamma_1 x_t + f^*(x_t) + u_t \tag{15}$$

where $\gamma_0+\gamma_1 x_t$ is the linear part of the relationship. Only when $f^*(x_t)=0$ there is a linear relationship between the variables. In this test the multiple of the rank transformation is used as $f^*(x_t)$.

If it is assumed that x_t is exogenous and u_t is a white noise with $u_t \sim N(0,\sigma^2)$ a *score test* is obtained as the $T^{*}R^2$ statistic of the MCO:

$$u_{\tilde{t}} = c_0 + c_1 x_t + c_2 R_t(x_t) + e_t \tag{16}$$

Bretuing (2001) generalizes the score test for the ECM representation and apply it to contrast the null hypothesis of linear cointegration against the alternative hypothesis of nonlinear cointegration.

To compute the score statistic, the following two multiple regressions are run consecutively:

$$y_t = \alpha_0 + \sum_{i=1}^{p} \alpha_{1i} y_{t-i} + \alpha_2 x_t + \sum_{i=-p}^{p} \alpha_{3i} \Delta x_{t-i} + u_t \quad (17)$$

$$\tilde{u}_t = \beta_0 + \sum_{i=1}^{p} \beta_{1i} y_{t-i} + \beta_2 x_t + \sum_{i=-p}^{p} \beta_{3i} \Delta x_{t-i} + \theta_1 R_T(x_t) + \tilde{v}_t \quad (18)$$

where $\beta_0 + \sum_{i=1}^{p} \beta_{1i} y_{t-i} + \beta_2 x_t + \sum_{i=-p}^{p} \beta_{3i} \Delta x_{t-i}$ is the linear part of the relationship and it involves the ranked series $R_T(x_{jt})$.

Under the null hypothesis, it is assumed that the coefficients for the ranked series are equal to zero, $\theta = 0$. The appropriate value of p is selected based on Akaike Information Criterion, such that serial correlation $\tilde{u}_t$ and possible endogeneity are adjusted based on Stock and Watson (1993). The *score statistic* $T \cdot R^2$, is distributed asymptotically as a χ^2 distribution, where T is the number of observations and R^2 is the coefficient of determination of the second equation. The null hypothesis may be rejected in favor of nonlinear relationship if the score statistic value exceeds the χ^2 critical values with one degree of freedom[1].

2. 4. *Granger Causality Rank Test*

To examine the casual linkage, conventional Granger causality test uses Vector Autoregression (VAR) or Vector Error Correction Model (VECM). However, results from the conventional parametric tests are limited by the augmenting hypothesis of the specific functional forms of the variables and the assumptions of homoscedasticity and normality of the error terms. As pointed by Ye Lim et al (2011), violation of these conditions can cause spurious causality conclusions. If one of these conditions is violated, Holmes and Hutton (1990) multiple rank F-test is more robust than the standard Granger causality test. Moreover, if the conditions of Granger estimations are satisfied, the multiple rank F-test results are alike the Granger results.

Holmes and Hutton (1990) analyzed the small sample properties of the multiple rank F-test, showing that with non-normal error distributions the test has significant power advantages both in small and in large sample. This is also true for weak and strong relationships between the variables.

The Holmes and Hutton (1990) multiple rank F-test is based on rank ordering of each variable. In this test, the causal relationship between y_t and x_t involves a test of a subset of *q* coefficients in the Autoregressive Distributed Lag (ARDL) model. The multiple rank F-test in ARDL (p,q) model can be written in the following framework:

$$R(y_t) = a_0 + \sum_{i=1}^{p} a_{1i} R(y_{t-i}) + \sum_{i=1}^{q} a_{2i} R(x_{t-i}) + e_t \quad (19)$$

$$R(x_t) = b_0 + \sum_{i=1}^{p} b_{1i} R(x_{t-i}) + \sum_{i=1}^{q} b_{2i} R(y_{t-i}) + \varepsilon_t \quad (20)$$

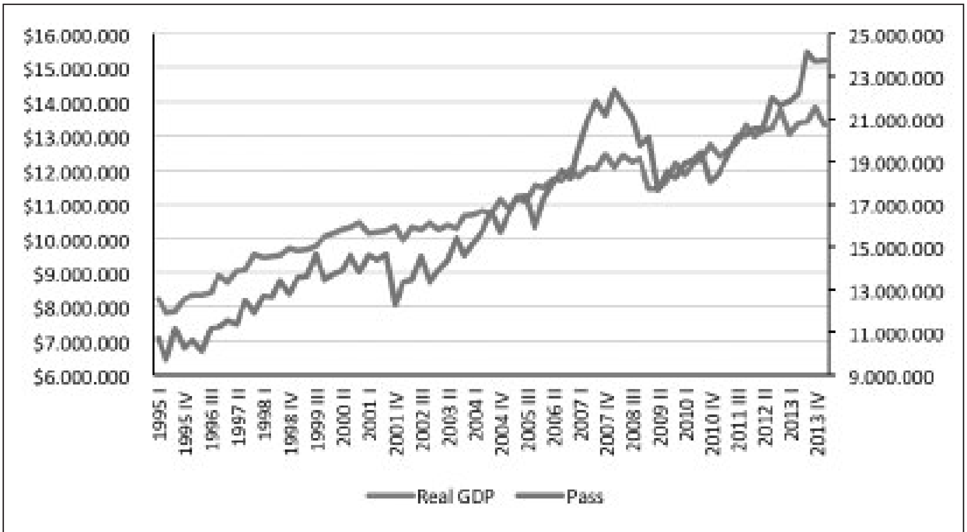
where $R(\cdot)$ represents a rank order transformation and, each lagged values of the series in each model are treated as separate variables when calculating their ranks,

[1] We consider 1 degree of freedom because the score test is applied using 2 variables.

for example, $R(y_t)$ and $R(y_{t-1})$. The residuals, e_t and ε_t are assumed to be serially uncorrelated. The values of *p* and *q* may differ in each equation. When choosing *p* and *q*, two things have to be considered: the significance of the estimated coefficients and the serial correlation of resulting residuals. From the first equation, rejection of the null hypothesis ($a_{2i} = 0$) implies causality from X to Y; whereas in the second one, rejection of the null hypothesis ($a_{2i} = 0$) implies the reverse causality from Y to X. The null hypothesis is rejected if the F-test statistic is significant with respective q´s value and N-K (K=p+q+1) degrees of freedom.

3. Data

Data used in this study are time series of quarterly data, ranging from the first quarter of 1995 through the last quarter of 2013. Real Gross Domestic Product (GDP) represents economic growth, and the number of passengers that travel by plane (Pass) represents the dynamics of air transportation. The *Pass* variable is defined as the number of domestic and international passengers carried by regular and non-regular commercial aviation, on both arrivals and departures. Charter domestic flights have been omitted for not being part of regular flights, and for not being offered by traditional marketing channels. Data on both variables were provided by the National Institute of Geography and Statistics (INEGI) of Mexico. For the empirical analysis variables in their logarithmic transformation are used: lnGDP and lnPass. Figure 1 illustrates the evolution of the involved variables.



Source: INEGI.

Figure 1. Real GDP and Number of passengers traveling by air to, from and within Mexico, 1995QI to 2014QI.

Figure 1 shows the link between the performance of economic activity and the number of passengers that travel by plane. Since 2002, air traffic has grown at an increasingly faster rate than the rest of Mexico's economy. A large proportion of the strong growth in additional international air passenger traffic since 2002 will have Mexico as its origin or final destination (IATA, 2009). The number of air passengers to and from Mexico has increased by around 122% since 1995, almost double of the real GDP growth.

4. Empirical results

The empirical exercise aims to apply both integration and cointegration tests proposed by Breitung (2002 and 2001) to analyze the existence of non-lineal relationship in the long run between real GDP and Number of passengers traveling by air to, from and within Mexico. Results are compared with those obtained by Brida et al (2016) within a linear framework.

In the first step, the order of integration is analyzed by applying the non-parametric unit root test proposed by Breitung (2002) to the series. The variance ratio statistic is employed to test the null hypothesis that y_t is I(1) against the alternative y_t is I(0). This is a left tailed test which indicates rejection for small values of the test statistic. Table 2 shows the results which indicate that both variables are integrated of order 1. These results are in line with those obtained by using the classic linear methodology (see Brida et al, 2016).

Table 2. Breitung non parametric test for unit roots.

Variable	Test spec.	$\hat{Q}_T$ Statistic	Critical value (5%)	Res.
Passengers	constant, trend and seasonal dummies	0.003486	0.00342	I(1)
Real GDP	constant, trend and seasonal dummies	0.003836	0.00342	I(1)

Note: Critical Values, Breitung (2002)

First order integrated series can present stationary combinations (I(0)), which implies the possible existence of a cointegration relationship between them. Since the introduction of the concept of cointegration, the analysis of cointegrated models has been intensively studied in a linear context. A general approach is provided by Johansen and Juselius (1990). This framework was applied in Brida et al (2016) to explore the existence of cointegration between Mexican Real GDP and Passengers. Results in this study indicate the existence of one cointegration vector, considering trace statistic test.

As explained before, the aim of this paper is to investigate the existence of a cointegration relationship between air transport and economic growth, without assuming the hypothesis of linearity of the underlying model. Once the existence of the cointegration relationship is confirmed, we proceed to its identification, investigating whether it is linear or not. Indeed, Breitung (2001) stated that when theory does not provide a precise specification of the functional form is desirable to have non-parametric tools for estimation and inference. In this article, the author proposes a rank test for detect cointegration, as it was explained in section 3.

Here, we estimate the non-parametric cointegration test following the method suggested by Breitung (2001). Table 3 resumes the empirical results. The non-parametric cointegration tests show that there is a cointegration relationship between real GDP and the number of airport passenger movements. These findings are similar to those obtained by Brida et al (2016) for the case of tourism and economic growth.

Table 3. Rank test for cointegration.

$\Xi^{*}_{T}[1]$	**Statistic**	**Critical value (5%)**	
Cramer von Mises	0.00809	0.0197	Reject.H0

Table 4. Test of Nonlinear Cointegration.

p=5	**Statistic**	**Critical value (5%)**	**Result**
Score statistic	3.553	3.84	No Reject H0
		Critical value (10%)	
Score statistic	3.553	2.7	Reject. H0

The next step implies checking the linearity of the long run relationship. Table 4 shows the results, indicating the existence of a linear cointegration relationship between real GDP and air transport.[1] Particularly, the test shows that this relationship is linear at the 5% level of confidence, and nonlinear at the 10% level. Therefore, it is possible to reject the existence of nonlinearities in the long-run relationship. Nevertheless, with a broader level of confidence the initial hypothesis of existence of nonlinearities in this linkage can be sustained.

Additionally and following Brida et al (2015), causality between both variables can be tested by applying the rank test proposed by Holmes and Hutton (1990). As explained before, this test is more robust than conventional parametric tests usually applied. Table 5 shows that the statistics (F, $\chi 2$) indicate the rejection of the restriction of nullity of coefficients a_{2i} and $b_{2i,}$ (eqs. 19 and 20).

[1] The score statistic is asymptotically Chi-square distributed under the null hypothesis of a linear cointegration relationship.

Table 5. Test of Nonlinear Causality (Holmes y Hutton, 1990)
H_0: $a_{21}=a_{22}=b_{21}=b_{22}=0$.

	Statistic	**Degrees of freedom**	**p-value**
F	25.028	(4, 66)	0.000
$\chi 2$	100.113	4	0.000
Normalized restriction (=0)		**Value**	**St. Error**
a_{21}		0.143	0.09
a_{22}		0.381	0.09
b_{21}		-0.205	0.07
b_{22}		0.338	0.08

Thus, the rank causality test confirms the bidirectional causality between air transport and economic growth in Mexico. This result is in line with those obtained in Brida et al (2016) by applying conventional causality test.

5. Conclusions

This paper introduces an alternative procedure for testing a cointegration relationship and causality between economic variables. When neither economic theory nor empiric evidence justifies the assumption of linearity of the linkages between the variables, one cannot assume that these relationships are linear without testing it. The correct sequence of steps to find a cointegration relationship should be: (i) testing the existence of cointegration by using no-parametric tests (ii) testing linearity or not, (iii) estimation of the corresponding relationship (iv) performing the rank-causality test. Failure to follow this procedure implies the assumption of a restricted approach in identifying procedures of equilibrium relationships between the involved variables, which in some cases can lead to non accurate conclusions. This procedure, together with the introduction of an alternative causality test is the main contributions of this study.

This article presents an application of the procedure to examine the long-run dynamic relationship between economic growth (represented by GDP) and air transport expansion (represented by the number of passengers) in Mexico. The study shows the importance of applying a more complete procedure for testing long-term relationships between two economic variables.

The non-parametric cointegration test confirms the existence of a cointegration relationship between economic growth and air transport for Mexico. The linearity test shows that nonlinearity is rejected at 5% level of confidence, but it was accepted at 10% level of confidence. This means that could be doubtful that the relationship between air transport and economic growth presents some kind of non-linear form. But, the test shows that the assumption of linearity is more robust. Following the procedure, the estimation of the linear cointegration relationship shows the existence of a positive relationship between the variables. Finally, the rank causality tests confirm the bidirectional causality between transport and growth. These tests are more robust than the conventional Granger Causality tests. These results confirm that air transport expansion plays a significant role in the long run economic growth of the country. The air transport industry should get policy attention to play its further ameliorated role in determining economic growth (Mehmood and Shahid, 2014).

Future research can include the study of other Latin-American countries to compare with the results of this paper. In particular, for those exercises where nonlinearities associated with the underlying model, the type of nonlinear relationship is identified.

References

Ablanedo-Rosas, J. H. and Gemoets, L. A. (2010). Measuring the efficiency of Mexican airports. *Journal of Air Transport Management 16* (6): 343-345 doi:10.1016/j.jairtraman.2010.05.003.

Breitung, J. (2001). Rank Test for Nonlinear Cointegration. *Journal of Business & Economics Statistics* 19(3): 331-340.

Breitung, J. (2002). Nonparametric tests for unit roots and cointegration. *Journal of Econometrics* 108: 343-363.

Brida, J. G., Lanzilotta, B., Pereyra J. S. and F. Pizzolón (2015). A nonlinear approach to the tourism led growth hypothesis: the case of the MERCOSUR. *Current Issues in Tourism* 18(7): 647-666.

Brida, J. G., Rodriguez Brindis, M. A. and Zapata Aguirre, S. (2016). Causality between economic growth and air transport expansion: empirical evidence from Mexico. *World Review of Intermodal Transportation Research* 6(1): 1-15 doi: 101504/writr.2016.078136.

Chang, Y. H., and Chang, Y. W. (2009). Air cargo expansion and economic growth: finding the empirical link. *Journal of Air Transport Management* 15(5): 264-265.

Chi, J. and Baek, J. (2013). Dynamic relationship between air transport demand and economic growth in the United States: A new look. *Transport Policy* 29: 257-260.

Davidson, J. (2002). Establishing conditions for the functional central limit theorem in nonlinear and semiparametric time series process. *Journal of Econometrics* 106, 243-269.

Fernandes, E. and Rodrigues Pacheco, R. (2010). The causal relationship between GDP and domestic air passenger traffic in Brazil. *Transportation Planning and Technology* 33(7): 569-581.

Fernandes, E., Pacheco, R. R. and Braga, M. E. (2014). Brazilian airport economics from a geographical perspective. *Journal of Transport Geography* 34: 71-77.

Granger, C. W. J. (1981). Some Properties of Time Series Data and Their Use in Econometric Model Specification. *Journal of Econometrics,* 16: 121-130.

Granger, C. W. J. (1993). What are we learning about the long-run? *The Economic Journal*, pp. 307-317.

Granger, C. W. J. (1995). Modelling Nonlinear Relationship Between Extended-memory Variables. *Econometrica* 63: 265-279.

Granger, C. W. J. and Hallman, J. (1991) Nonlinear Transformations of Integrated Time Series. *Journal of Time Series Analysis,* 12, 207-224.

Green, R. (2007). Airports and economic development. *Real Estate Economics* 35: 91-112.

Halpern, N. and Bråthen, S. (2011). Impact of airports on regional accessibility and social development. *Journal of Transport Geography* 19: 1145-1154.

Holmes, J. M. and Hutton, P. A. (1990). On The Causal Relationship Between Government Expenditures and National Income. *The Review of Economics and Statistics* 72(1): 87-95.

IATA (2009) Economic benefits from air transport in Mexico. Retrieved on October 10-2013from www.iata.org/economics

Johansen, S. (1988). Statistical analysis of cointegration vectors. *Journal of Economic Dynamics and Control* 12: 231-254.

Johansen, S. (1995). Likelihood-Based Inference in Cointegrated Vector Autoregressive Models, Advanced Texts in Econometrics, *Oxford University Press, Oxford*.

Johansen, S., and Juselius, K. (1990). Maximum likelihood estimation and inference on cointegration – with applications to the demand for money. *Oxford Bulletin of Economics and Statistics* 52(2): 169-210.

Lee, T.-H., White, H. and Granger, C. W. J. (1993). Testing for neglected nonlinearity in time series models: A comparison of neutral network methods and alternative test. *Journal of Econometrics* 56: 269-290.

Marazzo, M., Scherre, R. and Fernandes, E. (2010). Air transport demand and economic growth in Brazil: A time series analysis. Transportation Research Part E: *Logistics and Transportation Review* 46(2): 261-269.

Mehmood, B. and Shahid, A. (2014). Aviation Demand and Economic Growth in the Czech Republic: Cointegration Estimation and Causality Analysis. *Statistika* 94(1): 54-63.

Oxford Economics (2011). Economic Benefits from Air Transport in Mexico.

Özcan, I. Ç. (2013). Air passenger traffic and local employment: Evidence from Turkey. *European Journal of Transport and Infrastructure Research* 13(4): 336-356.

Stock, J. H. and Watson, M. W. (1993). A simple Estimator of Cointegrating Vector in Higher Order Integrated Systems. *Econometrica*61: 783-820.

Van De Vijver, E., Derudder, B., Witlox, F. (2014). Exploring causality in trade and air passenger travel relationships: The case of Asia-Pacific, 1980-2010. *Journal of Transport Geography* 34: 142-150.

Ye Lim, S. M. Ghazali, M. and Mun Ho, C. (2011). Export and economic growth in Southeast Asia current Newly Industrialized Countries: Evidence from nonparametric approach. *Economics Bulletin* 31(3): 2683-2693.

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