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Instituto de Estad\'istica

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Diciembre 2014

Documentos de Trabajo

Serie DT (14 /04) ISSN : 1688-6453

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September 2014

Abstract

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 significant effects on air transport expansion.

This paper analyzes the dynamic relationship between Mexican air transport (from the perspective of passengers' movement) and economic growth. By applying nonlinear techniques, we explore whether air transport leads -on the long run- to economic growth, or, alternatively, economic expansion drives air transport growth, or indeed a bi-directional relationship exists between the two variables. To this end, non-parametric cointegration and non-parametric causality test are applied to quarterly data of GDP and air passengers in Mexico for the period 1995-2013. Our results show that we cannot reject the existence of a linearity relationship between air transport and economic growth. The nonparametric causality tests, confirm bidirectional causality between transport and growth. Finally, the paper compares the results of the nonlinear approach with those obtained by using the traditional linear methodology.

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

JEL codes: C30; E43; L83

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1. Introduction

Air transportation may have strong positive effects on economic development and growth, producing what is called a direct causation. An issue that follows this observation is whether air transportation enhances economic development and growth, or vice versa, or whether they boost each other.

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.

Economic growth of a country 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 and Rodrigues Pacheco (2010) 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). Their main results show 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 air transport network and as most of the countries, benefits from the economic footprint of the industry. Air transport also has an important demand side contribution to Mexico's GDP through the value-added it creates. In 2010, the industry supported 158.000 jobs (direct, indirect and induced) in Mexico and contributed with 0.4% to Mexican GDP (IATA, 2009). If we take account for indirect or “catalytic” impacts from tourism, the contribution raises to 2.0% of GDP.

In a recent paper (Brindis, 2014) 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. This author shows that there exists a long-run equilibrium relationship between air transport industry and economic growth in Mexico and there is a bi-directional causality between them. Nevertheless, recent studies about the Tourism-led growth hypothesis, developed in a non-linear methodological framework (Brida et al, 2013), introduce a new perspective for the analysis of the relation between tradable sectors and the economic growth of the economies. In addition, the air transport activity (as was reported by Brindis (2014)) passed through some critical events that led us to the presumption that the relationship between the sector and the growth of the economy could take a nonlinear way.[1]

In this paper we analyze the dynamic relationship between Mexican air transport (from the perspective of passengers’ movement) and economic growth in a non-linear framework following the methodology proposed b breitung (2001, 2002). Non-parametric cointegration and non-parametric causality test are applied to quarterly data of GDP and air passengers in Mexico for the period 1995-2013. Additionally, the paper compares the results of the nonlinear approach with those obtained by using the traditional linear methodology.

The structure of the paper is as follows. In the next section, we briefly explain describes the methodological econometric framework. In section 3 we describe the data and give the empirical results. The final section discusses the results, offers concluding remarks, and indicates directions for future developments in this field.

2. Methodological framework: nonlinear analysis

Following Ye Lim et al (2011), we present the methodology for implementing nonparametric unit root test, cointegration test and Granger Causality test.

2.1 Nonparametric Unit Root Test

Breitung (2002) proposes the variance ratio statistic to test the integration degree avoiding the specification of the short-run dynamics or the estimation of nuisance parameters. The test is expressed by the following statistic equation:

[1] For example, the international economic crisis, the AH1N1 virus and the market withdrawal of Mexicana de Aviación.

$$T^{-1}\widehat{\rho_T} = \frac{T^{-4}\sum_{t=1}^{T}\widehat{U}_t^2}{T^{-2}\sum_{t=1}^{T}\hat{u}_t^2}$$

Where $\widehat{U}_t = \hat{u}_1 + \cdots + \hat{u}_t$ and $\hat{u}_t = y_t - \hat{\delta}' z_t$ are the ordinary least square (OLS) residuals from the regression of the data y_t on (i) $z_t = 0$, let $\hat{u} = y_t$, 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 assumes nonstationarity, I(1), under the null hypothesis against the alternative hypothesis I(0) process. 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

Breitung (2001) introduces a nonparametric test procedure based on ranks to test for cointegration. The idea of the rank test is that the sequences of the ranked series tend to diverge if there is no cointegration between the variables, and to evolve similarly under the alternative hypothesis. Breitung rank test checks whether the ranked series move together over time towards a linear o nonlinear long-term cointegrating equilibrium.

Firstly, we have to test for cointegration using the rank test, and if cointegration exists, it follows to examine the linearity of the cointegration relationship, by a scoring test.

The rank test procedure is based on the difference between the sequences of the ranks, so the cointegration can be detected by the following bivariate statistics:

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

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

where $d_t = R_T(y_t) - R_T(x_t)$, for $R_T(y_t)$ = Rank [of y_t among $y_1, \dots, y_T$] and $R_T(x_t)$ = Rank [of x_t among $x_1, \dots, x_T$]. The $\max_t |d_t|$ is the maximum value of $|d_t|$ over t=1,2, …, T and $\hat{\sigma}_{\Delta d}^2 = T^{-2}\sum_{t=2}^{T}(d_t - d_{t-1})^2$ serves to adjust for possible correlation between the two series of interest.

Furthermore, it is possible to generalize the test to cointegration among k+1 variables $y_t, x_{1t}, \dots, x_{kt}$, where it is assumed that $g(y_t)$ and $f(x_{jt})$ $(j = 1, \dots, k)$ are monotonic functions. Let $R_T(x_t) = [R_T(x_{1t}), \dots, R_T(x_{kt})]'$ 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 $\tilde{u}_t^R = R_T(y_t) - \tilde{b}_T' R_T(x_t)$, a multivariate rank statistic is obtained from the normalized sum of squares:

$$\Xi_T^*[k] = T^{-3} \sum_{t=1}^{T} (\tilde{u}_t^R)^2 \Big/ \hat{\sigma}_{\Delta\tilde{u}}^2$$

where $\hat{\sigma}_{\Delta\tilde{u}}^2 = T^{-2} \sum_{t=2}^{T} (\tilde{u}_t^R - \tilde{u}_{t-1}^R)^2$, again, serves to account for a possible correlation between series. The null hypothesis of no cointegration is rejected if the test statistic is below the respective critical value.

If cointegration exists in the first step, then we proceed to examine the linearity of the cointegration relationship. The score test is used 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:

$$y_t = \alpha_0 + \sum_{i=1}^{p} \alpha_{1i} y_{t-i} + \alpha_2 x_t + \sum_{i=-p}^{p} \alpha_{3i} \Delta x_{t-i} + \alpha_4 z_t + \sum_{i=-p}^{p} \alpha_{5i} \Delta z_{t-i} + u_t$$

$$\tilde{u}_t = \beta_0 + \sum_{i=1}^{p} \beta_{1i} y_{t-i} + \beta_2 x_t + \sum_{i=-p}^{p} \beta_{3i} \Delta x_{t-i} + \beta_4 z_t + \sum_{i=-p}^{p} \beta_{5i} \Delta z_{t-i} + \theta_1 R_T(x_t) + \theta_2 R_T(z_t) + \tilde{v}_t$$

Where $\beta_0 + \sum_{i=1}^{p} \beta_{1i} y_{t-i} + \beta_2 x_t + \sum_{i=-p}^{p} \beta_{3i} \Delta x_{t-i} + \beta_4 z_t + \sum_{i=-p}^{p} \beta_{5i} \Delta z_{t-i}$ 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, $\theta_1 = \theta_2 = 0$. 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. A significant $T \cdot R^2$ indicates that are nonzero, which can be taken as evidence of nonlinearity in cointegration. 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[2].

2.3 Nonparametric Granger Causality Test

To examine the casual linkage, conventional Granger causality test uses Vector Autoregression (VAR) or Vector Error Correction Model (VECM). However, results from the 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. Violation of these conditions can cause spurious causality

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

conclusions, as signaled by Ye Lim et al (2011). If one of these conditions is violated, Holmes and Hutton (1990) multiple rank F-test is shown to be more robust than the standard Granger causality test. Moreover, if the conditions of Granger estimations are satisfied, the multiple rank F-test results are similar to the Granger results. Holmes and Hutton (1990) analyzed the small sample properties of the multiple rank F-test, and found that with non-normal error distributions, the test has significant power advantages both in small and large sample as well as with 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:

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

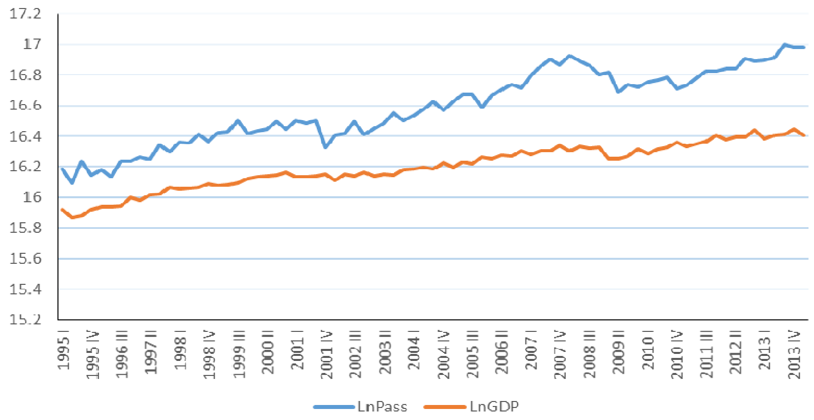
$$R(x_t) = b_0 + \sum_{i=1}^{p} b_{1i} R(x_{t-i}) + \sum_{i=1}^{q} a_{2i} R(y_{t-i}) + \varepsilon_t$$

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, 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, $a_{2i} \neq 0$, implies that there is causality from X to Y; whereas the second one shows 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 and results

Data applied in this study are quarterly time series, from 1995 to 2013, of real gross domestic product (GDP) to represent economic growth; and the number of airport passenger's movements to represent air transportation dynamic. Data from air transport passengers (Pass) and the real GDP series are provided by the National Institute of Geography and Statistics (INEGI). For the empirical analysis we use the variables in their logarithmic transformation, lnGDP and lnPass for the GDP and passengers' movements respectively.

Figure I. Real GDP and Number of passengers traveling by air to, from and within Mexico, 1995(Q.III) to 2013(Q.IV)



Source: Brida *et.al* (2014)

4. Empirical Results

Our empirical work 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.

Table I

Unit Root Test results: Variables in levels

H0		PIB real	Pass
The process is a random walk without drift	t-stat	-1.672	-0.951
	p-val	0.4457	0.7709
The process is a random walk with drift	t-stat	-1.672	-0.951
	p-val	0.0495	0.1726
The process is a random walk with trend	t-stat	-3.141	2.27
	p-val	0.0968	0.4508

Source: Brida *et.al* (2014).

Table II

Unit Root Test results: Variables in first difference

H0		PIB real
The process is a random walk without drift	t-stat	-6.376
	p-val	0
The process is a random walk with drift	t-stat	-6.376
	p-val	0
The process is a random walk with trend	t-stat	-6.356
	p-val	0

Source: Brida *et.al* (2014).

Tables I and II shows the results of parametric test for unit roots (variables are expressed in natural logarithms form) found by Brindis (2014) (with ADF methodology). ADFs test evidenced that both variables are non-stationary in levels and become stationary in their first differences. This means that real GDP and the number of passengers traveling by air are integrated of order one, I(1).

In this section the order of integration of the series is analyzed by applying the non-parametric unit root test proposed by Breitung (2002). The results are similar of those found by Brida *et. al* (2014)

Table III

Breitung non parametric test for unit roots

Passangers	$\hat{Q}_T$ Statistic	critical value (5%)	
constant, trend and seasonals	0.003486	0.00342	I(1)

Note: Critical Values, Breitung (2002)

Table IV

Breitung non parametric test for unit roots

Real GDP	$\hat{Q}_T$ Statistic	critical value (5%)	
constant, trend and seasonals	0.003836	0.00342	I(1)

Note: Critical Values, Breitung (2002)

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). Is a left tailed test that rejects for small values of the test statistic.

Table III and IV show the results. Results indicate that the variables are integrated of order 1, as we found with the classic linear methodology.

First order integrated series can present stationary linear combinations (I(0)), therefore, we have to study the possible existence of a cointegration relationship. A general approach is provided by Johansen and Juselius (1990). To determine if the variables are cointegrated and the number of cointegrating equations, Brida *et.al* (2014) used the trace test. The results of the Johansen cointegration tests are presented in Table V and detected the existence of one cointegration vector.

Table IV

Johansen Cointegration test

H_0: Number of cointegration equations	Include a restricted constant in model		Include a linear trend		Do not include a trend or a constant	
Trace Test[a]	Trace stat	5% Critical Value	Trace stat	5% Critical Value	Trace stat	5% Critical Value
None	24.39	19.96	17.8877*	18.17	19.0445	12.53
Almost1	4.5685*	9.42	4.115	3.74	0.0155*	3.84

*Indicates that this is the value of r selected by Johansen's r=1 r is the value selected by the procedure of Johansen's multiple-trace test procedure.

Surce: Brida *et.al* (2014)

Since the introduction of the concept of cointegration the analysis of cointegrated models has been intensively studied in a linear context. However, the empirical work on the extension to nonlinear cointegration is still limited.

Breitung (2001) stated that when theory does not provide a precise specification of the functional form is desiderable to have nonparametric tools for estimation and inference. In the article Breitung proposes a rank test for detect cointegration.

Here, we estimate the non-parametric cointegration test following the method suggested by Breitung (2001).

The results can be found in Table V. The non-parametric cointegration tests show that there is a cointegration relationship between real GDP and the number of airport passenger's movements to represent air transportation. These findings are in line with those obtained by the linear methodology.

Table V

Rank test for cointegration

$\Xi_T^*[2]$	Statistic	Critical value (5%)	
Cramer von Mises	0.00809	0.0188	Rech H0

In accordance with Breitung (2001), whenever the rank test for cointegration indicates a stable long run relationship, it is interesting to know whether the cointegration relationship is linear or nonlinear. The Table VI shows the results for the score test.

Table VI

Test of Nonlinear Cointegration

p=5	Statistic	Critical value (5%)	
Score statistic	3.553	3.84	No Rech H0
		(10%)	
Score statistic	3.553	2.7	Rech H0

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

The test result indicates that exist a cointegration relationship between real GDP and but is linear, at least at the 5% level of confidence. Therefore, contrary to our previous presumption, the results show that it is possible to reject the existence of nonlinearities in the long-run relationship between the evolution of GDP in Mexico and air transport.

Finally, in Table VII, we present the results of the Granger causality test, following the non parametric procedure proposed in Holmes and Hutton (1990).Remember that causal relationship between y_t (Real GDP) and x_t (Pass) 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:

X_t = log(Pass); y_t =log(Real GDP)

$R(X_t)$ = Rank transformation; $R(Y_t)$ = Rank transformation;

Eq.1

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

Table VIIa

Test of Nonlinear Causality (Holmes y Hutton, 1990)

Test Statistic	Value	df	Probability
F-statistic	25.02826	(4, 66)	0
Chi-square	100.1131	4	0

Table VIIb

Null Hypothesis: C(2)=C(4)=C(5)=C(6)=0
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
C(2)	0.1437	0.0905
C(4)	0.3818	0.0891
C(5)	-0.2054	0.0750
C(6)	0.3388	0.0811

Conclusion: log(Pass) -> log(Real GDP); Pass) -> Real GDP

Eq. 2

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

Table VIIIa

Test of Nonlinear Causality (Holmes y Hutton, 1990)

Test Statistic	Value	df	Probability
F-statistic	23.102	(3, 68)	0
Chi-square	69.30599	3	0

Table VIIIb

Null Hypothesis:
C(3)=C(4)=C(5)=0
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
C(3)	0.2693	0.1135
C(4)	-0.5703	0.1188
C(5)	0.6050	0.1370

Conclusion: log(Real GDP) -> log(Pass); Real GDP -> Pass

The results of these tests confirm the bidirectional causality from air transport to GDP in Mexico, as is was found by Brida *et.al* (2014) applying parametric tests.

5. Conclusions

The present article proposes a new approach to examine the relationship between GDP growth and air transportation sector for Mexico, by means of a non-linear methodology. We use quarterly series for the period 1995 to 2013, which allows us to perform a comparative analysis with those obtained by the classic linear methodology by Brida *et.al* (2014).

The non-parametric cointegration tests show that there is a cointegration relationship between economic growth and air transport for Mexico. However, nonlinearity was rejected at 5% level it was accepted at 10% level of confidence. This means that is doubtful that the relationship between tourism and growth shows some kind of asymmetry or non-linear behavior. Furthermore, the nonparametric causality tests, confirm the bidirectional causality between transport and growth.

Nevertheless, further analysis should be conducted to investigate the plausibility of nonlinearity in these sectors relationship considering other Latin-American countries, from a comparative perspective. One possible line for further research is to consider nonlinearities associated with the degree of specialization of each country as far as air transportation is concerned.

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