EXPORT LED GROWTH HYPOTHESIS: THE EFFECT OF DETERMINISTIC TERMS MISSPECIFICATION ON JOHANSEN COINTEGRATION TEST

Abstract

An important debate within the economic growth literature, centres whether countries should promote their export sector to obtain economic growth. Since the early nineties, most empirical literature on *Export Led Growth* consist on time series studies that focus on examining for Granger-causality between exports and growth over an individual country or a group of countries. Cointegration tests, like the Johansen procedure, are applied. Presumably, an important question to obtain reliable results from the Johansen cointegration test, that is usually omitted in most empirical works, is the specification of deterministic terms. In this paper we investigate by Monte Carlo simulation, the effect of deterministic parameters misspecification on the performance of Johansen´s likelihood ratio test when determining cointegrating rank in a vector error correction model. We find that results on Johansen cointegration test are very sensitive to the deterministic terms specification

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1. Introduction.

Within the economic growth literature, there are extensive references to the relationship between exports and economic growth. An important debate centres on whether countries should promote their export sector to obtain economic growth. Thus, abundant empirical literature on the *Export Led Growth* (ELG) hypothesis is available[1]. Since the early nineties, part of this literature consists on time series studies that focus on examining for causality between exports and growth over an individual country or a group of countries. These studies use the concept of causality developed by Granger (1969), where causality is synonymous of predictability, based on the idea that a cause can not come after an effect. The Granger-causality is generally tested after the estimation of a vector autoregressive model (VAR) for the export and growth variables. However, known the effects of Ordinary Least Squares (OLS) estimation of relationships between nonstationary variables, most of these studies apply cointegration tests as a preliminary step in the search for causality. The cointegration analysis allows to test for long-run equilibrium relationship between exports and growth, and avoids the possibility of obtaining spurious correlation[2].The most commonly used cointegration test are basically two: the Engle-Granger (EG) cointegration test developed in Engle and Granger (1987) and the procedure suggested by Johansen (1988). The principal difference between both tests is that while the EG test is a single equation method, the Johansen cointegration test is a system estimation method, where the number of cointegration vectors is not fixed *a priori* but determined in the course of estimation. Nevertheless, the Johansen procedure presents greater difficulty in practice. An important question, when applying this procedure, is the deterministic terms specification to be used, since results may differ from one specification to another. This question is ignored by virtually all the works reviewed on Table A1 (annex I) that applies the Johansen procedure.

In this paper we investigate by Monte Carlo simulation, the effect of deterministic parameters misspecification on the performance of Johansen´s likelihood ratio test when determining cointegrating rank in a vector error correction model.

[1] See Giles and Williams (2000a , 2000b) for an extensive review of the ELG empirical literature.
[2] See Granger and Newbold (1974)

The structure of the paper is as follows. In section 2, we briefly review the Johansen test procedure and the five possible specifications of vector error correction model depending on deterministic parameters. We also review the literature that have deal in some way with the impact of various formulations of deterministic terms on determining cointegrating rank through the Johansen test. In section 3 we first introduce the different data generating process (DGP) used in the simulation experiments. Then we present, in section 3.1, the results on determining cointegrating rank when deterministic parameters are misspecified. In section 3.2 we analyse the properties of the so called "*Pantula Principle*" for the simultaneous determination of cointegrating rank and deterministic components specification. Section 4 concludes.

2. Deterministic components.

Consider the vector autoregressive (VAR) of *k* order model,

$$X_t = \Phi_1 X_{t-1} + \ldots + \Phi_k X_{t-k} + \mu + \varepsilon_t , \quad t = 1, \ldots, T \tag{1.1}$$

for a $(p \times 1)$ vector X_t of I(1) variables, where ε_t represents a $(p \times 1)$ vector of Gaussian random variables with mean zero and variance matrix Σ_ε. For cointegration analysis, it is convenient to express this equation in error correction form (VECM),

$$\Delta X_t = \Pi X_{t-k} + \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \mu + \varepsilon_t , \quad t = 1, \ldots, T \tag{1.2}$$

with

$$\Pi = -I + \sum\nolimits_{i=1}^{k} \Phi_i \tag{1.3}$$

and

$$\Gamma_i = -\sum\nolimits_{j=i+1}^{k} \Phi_j \tag{1.4}$$

The matrix Π contains information on cointegrating relations between the p elements of X_t. When $0 < \text{rank}(\Pi) = r < p$, then Π has reduced rank and we can rewrite it as,

$$\Pi = \alpha\beta' \tag{1.5}$$

where α is a $(p \times r)$ matrix of error correction vectors and β is a $(p \times r)$ matrix of cointegrating vectors so that $\beta' X_t$ is stationary although X_t itself is nonstationary. The maximum likelihood cointegration test method, developed in Johansen (1988), tests the rank of the matrix Π using the reduced rank regression technique based on canonical correlations. In the case of no deterministic components, it consists in computing the residuals R_{kt} and R_{0t} from ordinary least squares regression of X_{t-k} and ΔX_t on the lagged differences, $\Delta X_{t-1}, \ldots$, and ΔX_{t-k+1}. The product moment matrices are then given by

$$S_{ij} = T^{-1} \sum R_{it} R'_{jt} \tag{1.6}$$

Where $i,j = 0,k$ and the eigenvalues $\hat{\lambda}_1 > \ldots > \hat{\lambda}_p$ are the solutions from

$$\left| \lambda S_{kk} - S_{k0} S_{00}^{-1} S_{0k} \right| = 0 \tag{1.7}$$

The likelihood ratio test statistic (trace test) for the hypothesis that there are at most r cointegration vectors is,

$$TR = -T \sum_{i=r+1}^{p} \ln(1 - \hat{\lambda}_i) \tag{1.8}$$

The Johansen procedure presents in practice, several difficulties associated with the initial specification of the VECM that can lead to wrong conclusions. Basically, a proper specification of the VECM to provide reliable results on the existence of long run equilibrium among the variables of interest, requires a dual election; (i) first, it is important to correctly specify the short run dynamics of the model, through an appropriate choice of the VECM order or value of k in (1.2), (ii) secondly it is advisable to choose the model that best reflects the properties of the series, trough the correct specification of deterministic components.

Without loss of generality, we can suppose that μ is the sum of a constant term (μ_0) and a linear trend ($\mu_1 t$). Now vectors μ_0 and μ_1 can each be decomposed into two new vectors, so we now have 5 different specifications [see Johansen (1995), Hendry and Juselius (2001)],

$$\mu_i = \alpha\rho_i + \alpha_\perp \gamma_i , \quad i = 0,1 \tag{1.9}$$

where $\alpha_\perp$ is the orthogonal complement of matrix α (so $\alpha'_\perp \alpha_\perp = 0$) , $\rho_i = (\alpha'\alpha)^{-1}\alpha'\mu_i$ and $\gamma_i = (\alpha'_\perp \alpha_\perp)^{-1}\alpha'_\perp \mu_i$. In order to facilitate the analysis we suppose that k = 1 so that it is possible to rewrite (1.2) as,

$$\Delta X_t = \alpha\beta' X_{t-1} + \alpha\rho_0 + \alpha_\perp\gamma_0 + \alpha\rho_1 t + \alpha_\perp\gamma_1 t + \varepsilon_t \tag{1.10}$$

so, collecting terms in (1.10) yields,

$$\Delta X_t = \alpha(\beta' X_{t-1} + \rho_0 + \rho_1 t) + \alpha_\perp\gamma_0 + \alpha_\perp\gamma_1 t + \varepsilon_t \tag{1.11}$$

Table 1 shows the VECM representation for each of the five different specifications of the deterministic components. The estimation procedure and the TR test asymptotic properties for Model 1 can be found in Johansen (1988). Models 2 and 3 are analyzed in Johansen and Juselius (1990) and Johansen (1991). Models 4 and 5 are treated in Johansen (1994), although all of them are analyzed in Johansen (1995)

Table 1. VECM representation.

Model	Deterministic components μD_t	VECM
M5	$\alpha\rho_0 + \alpha_\perp\gamma_0 + (\alpha\rho_1 + \alpha_\perp\gamma_1)t$	$\Delta X_t = \alpha(\beta' X_{t-1} + \rho_0 + \rho_1 t) + \alpha_\perp\gamma_0 + \alpha_\perp\gamma_1 t + \varepsilon_t$
M4	$\alpha\rho_0 + \alpha_\perp\gamma_0 + \alpha\rho_1 t$	$\Delta X_t = \alpha(\beta' X_{t-1} + \rho_0 + \rho_1 t) + \alpha_\perp\gamma_0 + \varepsilon_t$
M3	$\alpha\rho_0 + \alpha_\perp\gamma_0$	$\Delta X_t = \alpha(\beta' X_{t-1} + \rho_0) + \alpha_\perp\gamma_0 + \varepsilon_t$
M2	$\alpha\rho_0$	$\Delta X_t = \alpha(\beta' X_{t-1} + \rho_0) + \varepsilon_t$
M1	0	$\Delta X_t = \alpha\beta' X_{t-1} + \varepsilon_t$

As can be seen from the table 1, Model 1 is the most restrictive since it corresponds to a model with no deterministic components in the data. In Model 2, the only deterministic component is a restricted constant within the cointegration space. Thus, the model implies no linear trends in the data and that the equilibrium mean is different from zero. Model 3 has an unrestricted constant outside the cointegration space. The model implies both linear trends in the level of X_t and non-zero intercept in the cointegration relations. Model 4 has a restricted trend within the cointegration space and an unrestricted constant. This model implies linear trends in the data that do not cancel in the cointegration relations. Finally Model 5 has an unrestricted trend and constant outside the cointegration space, so that is consistent with the presence of quadratic trends in the data.

Model specification is far from been a simple task, although sometimes there may be economic grounds to prefer one specification to others. Nevertheless, visual inspection of the data together with univariate analysis, offer some clues that do facilitate the specification of deterministic components in the VECM.

Alternatively, based on Pantula (1989), Johansen (1992, 1995: chapter 12) suggests a procedure to simultaneously determine rank and deterministic components in cointegrated VAR models. This method called “Pantula Principle”, included in some widely used econometric software like CATS in RATS, is useful in situations in which researcher doubts between Model 2 or Model 3 and between Model 4 or Model 5.
In this two cases, the procedure is carried out respectively by sequentially testing the following hypothesis

$$H_2(0), H_3(0), H_2(1), H_3(1), \ldots, H_2(p-1), H_3(p-1) \quad (1.12)$$

$$H_4(0), H_5(0), H_4(1), H_5(1), \ldots, H_4(p-1), H_5(p-1) \quad (1.13)$$

where H_i (r) is the null hypothesis of cointegrating rank to be equal "r" in "Model i" against the unrestricted alternative. The process stops whenever the hypothesis is not rejected, determining cointegration rank and the model that fits better the components properties of vector X_t. In some empirical works, this procedure is not limited to the two mentioned situations, but rather it is applied to the five possible models, a practice that can lead, as we will demonstrate later, to erroneous results.

There are several works that have treated the problem of deterministic components specification in Johansen procedure. Toda (1995), analyzed trough simulation the properties of the TR test for Model 2 and Model 3, as well as the capacity of the "Pantula Principle" to jointly determine cointegration rank and deterministic components specification. The author notes that, although the procedure leads us in general to correctly determine cointegration rank, systematically fails in detecting the presence of linear trend in the data. That is, the procedure usually suggests specifying Model 2 even when the true process is Model 3. Doornik et al (1998) analyzed the effect of an incorrect specification of the deterministic components when testing for cointegration rank. These authors use in their simulation experiments, a data generating process (DGP) with a restricted trend within the cointegration space (Model 4), obtaining two important outcomes to emphasize. Firstly, they observe that a wrong specification of deterministic terms leads to a wrong cointegration rank. The authors find evidence that the non inclusion of a restricted trend when it is present in the DGP generates distortions in the test size, while the inclusion of an unrestricted trend is problematic since leads to a loss of test power. Secondly, they appreciate that a restricted trend in the cointegration space and unrestricted constant produce good power and reasonable size, even when the true DGP have no trend and even no constant. The initial specification of Model 4 seems to be a cautious choice when the researcher ignores the specific form of the deterministic components in the VECM. Gonzalo and Lee (1998) demonstrate that in those cases where the presence of deterministic components is omitted, the Johansen procedure leads to spurious cointegration with probability approaching one asymptotically. Nielsen and Rahbek (2000), found that only for Model 2 and Model 4, the Johansen TR test is asymptotic similar with respect to the deterministic parameters. This means that the hypothesis on cointegration rank can be analysed separately from deterministic parameters. Therefore, cointegration analysis should be carried out in two stages. Firstly cointegration rank should be determined by means of a model in which the TR test is similar. Secondly, once the rank determination has been settled, inference on remaining parameters such deterministic ones should be made. Franses (2001) offers some practical advice for the specification of the deterministic components in cointegration analysis. The author suggests that only two of the five possible models are attractive in cointegration analysis among economic variables: Model 2, which is useful when none of the series shows trend and Model 4 that, should be used when some or all the series shows trend. Lastly, Ahking (2002) finds that results on cointegration rank when analyzing the money demand in the United States is quite sensitive on the specification of deterministic parameters. The author exposes repeatedly, the lack of attention given to this fact in most empirical works and points out that none of previous studies gives a formal justification of the deterministic components specification employed.

3. Simulation.

In order to investigate the impact of deterministic components specification on determining cointegration rank, we have carried out several Monte Carlo simulations. Moreover, we analyse whether the "Pantula Principle" is a reliable procedure to jointly determine cointegration rank and deterministic components.

Through the simulations three different DGP have been used, all of which are specific cases of the following one[3],

$$\underbrace{\begin{pmatrix} \Delta X_{1t} \\ \Delta X_{2t} \end{pmatrix}}_{\Delta X_t} = \underbrace{\begin{pmatrix} \mu_{01} \\ \mu_{02} \end{pmatrix}}_{\mu_0} + \underbrace{\begin{pmatrix} \mu_{11} \\ \mu_{12} \end{pmatrix}}_{\mu_1} t + \underbrace{\begin{pmatrix} \alpha_1 \\ 0 \end{pmatrix} \begin{pmatrix} 1 & -1 \end{pmatrix}}_{\alpha\beta'} \underbrace{\begin{pmatrix} X_{1t-1} \\ X_{2t-1} \end{pmatrix}}_{X_{t-1}} + \underbrace{\begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{pmatrix}}_{\varepsilon_t} \quad (1.14)$$

where

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[3] See Annex II.

$$\varepsilon_t \sim iid\ N\left[\begin{pmatrix}0\\0\end{pmatrix},\begin{pmatrix}2\theta+2 & \theta+1\\ \theta+1 & 1\end{pmatrix}\right] \tag{1.15}$$

If we decompose vectors μ_0 and μ_1 as in (1.9), it is possible to rewrite (1.14) as,

$$\begin{pmatrix}\Delta X_{1t}\\ \Delta X_{2t}\end{pmatrix}=\begin{pmatrix}0\\ \alpha_{\perp 2}\end{pmatrix}\gamma_0+\begin{pmatrix}0\\ \alpha_{\perp 2}\end{pmatrix}\gamma_1 t+\begin{pmatrix}\alpha_1\\ 0\end{pmatrix}\left[\begin{pmatrix}1 & -1\end{pmatrix}\begin{pmatrix}X_{1t-1}\\ X_{2t-1}\end{pmatrix}+\rho_0+\rho_1 t\right]+\begin{pmatrix}\varepsilon_{1t}\\ \varepsilon_{2t}\end{pmatrix} \tag{1.16}$$

Now, our three DGP take the following form,

DGP₂ $$\underbrace{\begin{pmatrix}\Delta X_{1t}\\ \Delta X_{2t}\end{pmatrix}}_{\Delta X_t}=\underbrace{\begin{pmatrix}\alpha_1\\ 0\end{pmatrix}\rho_0}_{\mu_0}+\underbrace{\begin{pmatrix}\alpha_1\\ 0\end{pmatrix}\begin{pmatrix}1 & -1\end{pmatrix}}_{\alpha\beta'}\underbrace{\begin{pmatrix}X_{1t-1}\\ X_{2t-1}\end{pmatrix}}_{X_{t-1}}+\underbrace{\begin{pmatrix}\varepsilon_{1t}\\ \varepsilon_{2t}\end{pmatrix}}_{\varepsilon_t}$$

DGP₃ $$\underbrace{\begin{pmatrix}\Delta X_{1t}\\ \Delta X_{2t}\end{pmatrix}}_{\Delta X_t}=\underbrace{\begin{pmatrix}\alpha_1\\ 0\end{pmatrix}\rho_0+\begin{pmatrix}0\\ \alpha_{\perp 2}\end{pmatrix}\gamma_0}_{\mu_0}+\underbrace{\begin{pmatrix}\alpha_1\\ 0\end{pmatrix}\begin{pmatrix}1 & -1\end{pmatrix}}_{\alpha\beta'}\underbrace{\begin{pmatrix}X_{1t-1}\\ X_{2t-1}\end{pmatrix}}_{X_{t-1}}+\underbrace{\begin{pmatrix}\varepsilon_{1t}\\ \varepsilon_{2t}\end{pmatrix}}_{\varepsilon_t}$$

DGP₄ $$\underbrace{\begin{pmatrix}\Delta X_{1t}\\ \Delta X_{2t}\end{pmatrix}}_{\Delta X_t}=\underbrace{\begin{pmatrix}\alpha_1\\ 0\end{pmatrix}\rho_0+\begin{pmatrix}0\\ \alpha_{\perp 2}\end{pmatrix}\gamma_0}_{\mu_0}+\underbrace{\begin{pmatrix}\alpha_1\\ 0\end{pmatrix}\rho_1 t}_{\mu_1 t}+\underbrace{\begin{pmatrix}\alpha_1\\ 0\end{pmatrix}\begin{pmatrix}1 & -1\end{pmatrix}}_{\alpha\beta'}\underbrace{\begin{pmatrix}X_{1t-1}\\ X_{2t-1}\end{pmatrix}}_{X_{t-1}}+\underbrace{\begin{pmatrix}\varepsilon_{1t}\\ \varepsilon_{2t}\end{pmatrix}}_{\varepsilon_t}$$

These PGD are representative of Model 2, Model 3 and Model 4. We excluded Model 1 and Model 5 since they are not appropriate for economic data. All three DGP are bivariate models with no lags. Figures 3, 4 and 5 show series randomly generated by DGP_2, DGP_3 and DGP_4 and the resulting cointegration vector. As expected, series on Figure 4 and 5 shows a clear linear trend, while this is not the case for Figure 3.

Figura 3 PGD$_2$: α_1 = -0,5 , θ= 0,8 y T = 200.

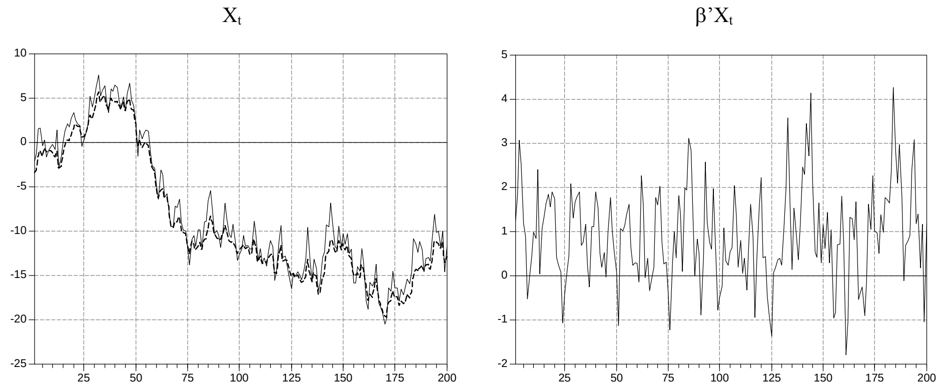


Figura 4 PGD$_3$: α_1 = -0,5 , θ= 0,8 y T = 200.

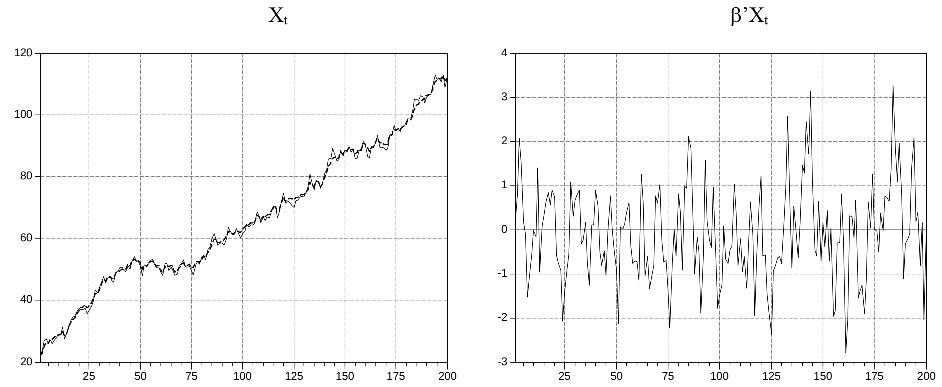
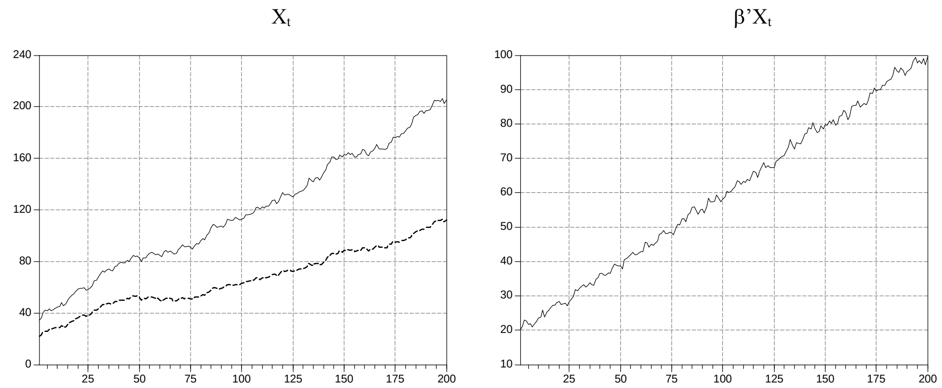


Figura 4 PGD$_4$: α_1 = {-0,5 ; -0.1} , θ= 0,8 y T = 200.



In our simulation experiments, the estimated model is always a bivariate VECM with no lags, so that short run dynamics is correctly specified. In all cases the number of replications is 10,000. The initial values for variables X_1 and X_2 has been set to zero and the first 50 observations have been discarded to minimize the effects associated to this initial condition. Common random numbers were used for all experiments, generated through the Matlab Software function *mvnrnd* that uses the "*ziggurat*" algorithm developed by Marsaglia y Tsang (1984). So, all results tables were based on the same data.

3.1 Deterministic components and the TR test performance.

In tables 2.a and 2.b, results on TR test performance are reported. Each column shows the frequency (%) of deciding cointegrating rank to be one (table 2.a) and to be zero (table 2.b) for a given combinations of the values of parameters that affect test performance. The cointegration rank is determined according to the sequential procedure described in Johansen (1995) that ensures the correct asymptotic size of the test. This procedure starts testing the hypothesis that the cointegrating rank is equal to zero. If the hypothesis is not rejected the cointegrating rank is decided to be zero. If rejected the hypothesis that cointegrating rank is equal to one is then tested. If this hypothesis is not rejected, the cointegrating rank is taken to be one. The asymptotic size of the test is 5%, so that figures in table 2.a near 95% indicates good test performance. In this first experiment, for each DGP the model is correctly specified in terms of deterministic components.

Table 2.a Performance of TR test (s = 1)
DGP_2 : r = 1 , $\rho_0 = -1$
DGP_3 : r = 1 , $\rho_0 = -1$, $\gamma_0 = 1$
DGP_4 : r = 1 , $\rho_0 = -1$, $\gamma_0 = 1$, $\rho_1 = -0.4$

		$\alpha_1 = -0.5$		$\alpha_1 = -0.3$		$\alpha_1 = -0.1$	
		$\theta = 0.8$	$\theta = 0.0$	$\theta = 0.8$	$\theta = 0.0$	$\theta = 0.8$	$\theta = 0.0$
DGP_2	25	69.00	18.27	35.17	9.39	11.31	5.90
	50	94.65	61.02	82.61	22.46	21.46	6.44
	75	95.01	90.82	94.22	47.55	37.64	8.57
	100	94.74	95.20	94.68	73.31	55.59	11.26
	150	95.19	95.49	95.11	94.40	83.55	21.08
	200	95.02	95.27	95.01	95.22	92.96	35.01
	400	94.89	94.85	94.61	94.90	94.40	90.23
DGP_3	25	69.89	21.09	32.98	9.63	7.77	5.49
	50	92.08	71.02	82.87	27.49	17.00	6.73
	75	92.72	92.60	91.75	57.74	33.86	9.05
	100	93.70	94.16	93.07	82.58	54.10	12.85
	150	94.13	94.41	93.72	94.47	83.73	25.11
	200	93.91	94.73	93.49	94.91	91.47	43.80
	400	94.58	94.85	94.31	94.88	93.71	93.82
DGP_4	25	54.80	16.17	26.16	9.72	9.61	6.93
	50	93.02	48.82	70.23	18.50	14.78	6.87
	75	93.62	83.33	90.77	36.41	26.97	8.12
	100	94.22	93.27	93.77	60.21	40.47	10.78
	150	94.44	94.70	94.17	90.52	71.81	17.05
	200	94.53	94.97	94.41	94.79	88.05	27.29
	400	94.45	94.24	94.37	94.23	93.75	82.28

Table 2.b Performance of TR test (s = 0)

DGP_2 : r = 1 , ρ_0 = -1

DGP_3 : r = 1 , ρ_0 = -1 , γ_0 = 1

DGP_4 : r = 1 , ρ_0 = -1 , γ_0 = 1 , ρ_1 = -0.4

		α_1 = -0.5		α_1 = -0.3		α_1 = -0.1	
		θ = 0.8	θ = 0.0	θ = 0.8	θ = 0.0	θ = 0.8	θ = 0.0
	25	25.67	79.68	60.66	89.71	87.14	93.55
	50	0.23	34.88	12.45	75.08	75.93	92.89
	75	0.00	4.66	0.66	48.78	58.67	90.68
DGP_2	100	0.00	0.23	0.00	22.42	39.69	87.49
	150	0.00	0.00	0.00	1.18	11.53	76.71
	200	0.00	0.00	0.00	0.00	1.64	61.70
	400	0.00	0.00	0.00	0.00	0.00	5.04
	25	20.64	74.49	58.82	87.88	88.74	92.86
	50	0.05	23.30	8.44	68.57	77.27	91.81
	75	0.00	1.49	0.18	37.09	58.72	89.06
DGP_3	100	0.00	0.04	0.00	12.15	37.68	84.97
	150	0.00	0.00	0.00	0.13	8.22	71.80
	200	0.00	0.00	0.00	0.00	0.86	52.31
	400	0.00	0.00	0.00	0.00	0.00	1.42
	25	39.56	82.43	70.59	89.67	89.41	92.64
	50	0.95	47.06	24.10	79.55	83.71	92.51
	75	0.00	11.35	2.81	59.92	70.04	91.30
DGP_4	100	0.00	1.06	0.05	34.87	55.33	88.22
	150	0.00	0.00	0.00	4.36	22.80	81.31
	200	0.00	0.00	0.00	0.17	5.99	70.16
	400	0.00	0.00	0.00	0.00	0.00	12.37

Results shows that the performance of TR test is very sensitive to the value of θ, which is the correlation between U_{1t} and U_{2t} in (5.29). For a given value of α_1, the test performs better for $\theta = 0.8$ than for $\theta = 0.0$. Also, the test can not detect well the true cointegrating rank for values of α_1 close to zero. For α_1 = -0.1, sample sizes over 400 are needed to get a good test performance even when θ takes large values. For α_1 = -0.5 and $\theta = 0.8$ the TR test performs quite well even for small sample sizes (above 50). So we take these values of α_1 and θ as fixed for the following experiments.

The results of the effect of deterministic components misspecification on cointegrating rank determination are reported on table 3 and table 4. In table 3, each column shows the frequency (%) in which the TR test indicates cointegration rank to be equal to "s" (s = 0,1), for a given specification of deterministic parameters (Model 1 to Model 5) and for the three DGP described before. Again, the asymptotic size of the test is 5%, so that figures near 95% for s=1 indicates good test performance. The values in columns for s=0 indicate the probability of Type II error.

Table 3 Performance of TR test

DGP_2 : r = 1 , α_1 = -0.5 , θ = 0.8 , ρ_0 = -1

DGP_3 : r = 1 , α_1 = -0.5 , θ = 0.8 , ρ_0 = -1 , γ_0 = 1

DGP_4 : r = 1 , α_1 = -0.5 , θ = 0.8 , ρ_0 = -1 , γ_0 = 1 , ρ_1 = -0.4

		Estimated Model									
DGP	T	Model 1		Model 2		Model 3		Model 4		Model 5	
		s = 0	s = 1	s = 0	s = 1	s = 0	s = 1	s = 0	s = 1	s = 0	s = 1
	25	20.12	73.99	25.67	69.00	13.94	53.93	39.56	54.80	14.67	24.02
	50	1.15	92.45	0.23	94.65	0.04	67.05	0.95	93.02	0.09	34.69
	75	0.02	93.73	0.00	95.01	0.00	67.72	0.00	93.62	0.00	35.42
DGP_2	100	0.00	93.70	0.00	94.74	0.00	67.75	0.00	94.22	0.00	35.46
	150	0.00	93.82	0.00	95.19	0.00	68.26	0.00	94.44	0.00	35.94
	200	0.00	93.86	0.00	95.02	0.00	67.81	0.00	94.53	0.00	36.23
	400	0.00	93.94	0.00	94.89	0.00	67.47	0.00	94.45	0.00	35.30
	25	0.00	11.93	0.04	58.79	20.64	69.89	39.56	54.80	14.67	24.02
	50	0.00	0.15	0.00	9.97	0.05	92.08	0.95	93.02	0.09	34.69
	75	0.00	0.00	0.00	0.34	0.00	92.72	0.00	93.62	0.00	35.42
DGP_3	100	0.00	0.00	0.00	0.00	0.00	93.70	0.00	94.22	0.00	35.46
	150	0.00	0.00	0.00	0.00	0.00	94.13	0.00	94.44	0.00	35.94
	200	0.00	0.00	0.00	0.00	0.00	93.91	0.00	94.53	0.00	36.23
	400	0.00	0.00	0.00	0.00	0.00	94.58	0.00	94.45	0.00	35.30
	25	51.80	38.28	55.52	39.73	73.60	24.45	39.56	54.80	14.67	24.02
	50	28.26	54.19	34.46	58.40	70.19	29.53	0.95	93.02	0.09	34.69
	75	13.70	64.49	16.93	74.06	70.01	29.95	0.00	93.62	0.00	35.42
DGP_4	100	4.26	71.58	6.04	82.86	69.46	30.53	0.00	94.22	0.00	35.46
	150	0.07	74.25	0.12	86.30	70.39	29.61	0.00	94.44	0.00	35.94
	200	0.00	73.42	0.00	85.33	69.87	30.13	0.00	94.53	0.00	36.23
	400	0.00	72.43	0.00	82.37	69.56	30.44	0.00	94.45	0.00	35.30

Results highlight the adequacy of a correct specification of deterministic terms on Johansen cointegration test. For DGP_2 the TR test performs good when estimating Models 1,2 and 4. In this case, ignoring the presence of a non-zero intercept in the cointegration relations does not affect the test performance. When Models 3 and 5 are estimated, the test performance is poor, so that the frequencies in which the TR test indicates cointegrating rank to be equal one are below 69% and 36% respectively. For DGP_3, when estimating Model 1 and Model 2 the frequencies in which the TR test tells the true cointegrating rank, tend to zero as the sample size increases. Thus, ignoring the presence of an unrestricted constant in the VECM leads to size distortions with probability of committing a Type I error approaching one as sample sizes are larger. We only get a good test performance when estimating Model 3 and Model 4. Finally, for DGP_4 we only get a good test performance when Model 4 is estimated. The estimation of Model 1 and Model 2, gives frequencies for s = 1 around 72% and 82% respectively for large sample sizes.

Table 4 shows the results on the TR test performance for DGP_2 and DGP_3[4] in the case in which the cointegrating rank is zero. Now figures near 95% for s=0 indicates good test performance.

Table 4 Performance of TR test
DGP_2 : $r = 0$, $\alpha_1 = 0$, $\theta = 0.8$
DGP_3 : $r = 0$, $\alpha_1 = 0$, $\theta = 0.8$, $\gamma_0 = 1$

		Estimated Model									
DGP	T	M1		M2		M3		M4		M5	
		s = 0	s = 1	s = 0	s = 1	s = 0	s = 1	s = 0	s = 1	s = 0	s = 1
	25	94.17	5.06	93.16	6.21	87.10	6.95	92.75	6.81	75.44	6.04
	50	95.18	4.23	93.95	5.60	87.77	6.58	93.45	6.06	77.19	5.41
	75	95.30	4.11	94.07	5.46	87.72	6.80	93.83	5.70	77.18	5.45
DGP_2	100	95.34	4.13	93.82	5.76	88.01	6.62	93.87	5.67	77.28	5.58
	150	95.36	4.02	93.96	5.48	88.26	6.18	93.75	5.81	77.60	5.20
	200	95.20	4.20	94.52	5.04	88.70	6.05	93.78	5.74	78.41	4.84
	400	95.24	4.22	94.39	5.17	88.11	6.40	94.14	5.43	77.79	5.13
	25	0.00	71.51	0.00	83.09	93.35	5.32	92.75	6.81	75.44	6.04
	50	0.00	72.79	0.00	83.36	94.13	4.75	93.45	6.06	77.19	5.41
	75	0.00	73.13	0.00	83.75	94.27	4.77	93.83	5.70	77.18	5.45
DGP_3	100	0.00	73.67	0.00	83.91	94.60	4.36	93.87	5.67	77.28	5.58
	150	0.00	73.36	0.00	83.87	94.67	4.47	93.75	5.81	77.60	5.20
	200	0.00	73.48	0.00	84.12	94.99	4.23	93.78	5.74	78.41	4.84
	400	0.00	73.49	0.00	83.50	94.87	4.39	94.14	5.43	77.79	5.13

For DGP_2 , when Models 1, 2 and 4 are estimated, the frequencies in which the TR test does not reject the null hypothesis of no cointegration, takes values close to the asymptotic size of the test. When Model 1 is estimated, this happens even for low sample sizes. If Model 3 or Model 5 is estimated, the test performance is poor. For DGP_3 only when estimating Model 3 and Model 4, the TR test performs correctly. When Model 1 and Model 2 are estimated, the frequencies in which the test indicates no cointegration, takes value zero for every sample size. Again, the omission of linear trend in data generates size distortions, with probability of Type I error equal 1. In this case the TR test can lead too often to accept the presence of cointegration.

Lastly, as demonstrated by Nielsen and Rahbek (2000), it can be shown that rank hypothesis testing over Model 2 and Model 4 leads to asymptotic TR test distributions which do not depend on the deterministic parameters of the models. Thus, cointegration rank can be analysed in this two models separately from deterministic terms. Tables 5, 6 and 7, report the frequencies in which the TR test indicates cointegrating rank to be

[4] For $\alpha_1 = 0$, DGP_3 and DGP_4 are the same, so there is no need to present the results for the latter

equal *s*, for DGP_2, DGP_3 and DGP_4 respectively and different values of deterministic parameters. Notice that for DGP_2, when Model 2 is estimated, these frequencies are identical for different values of ρ_0. The same result holds for DGP_4 when Model 4 is estimated for different values of ρ_1. In the case of DGP_3, the frequencies vary depending on the value of γ_0. As this parameter takes values close zero, that is the intercept of the cointegration relation vanishes, the performance of TR test declines.

Table 5 Performance of TR test
DGP_2 : $r = 1$, $\alpha_1 = -0.5$, $\theta = 0.8$, $\rho_0 = \{-0.5 , -0.1\}$

		Estimated Model									
ρ_0	T	Model 1		Model 2		Model 3		Model 4		Model 5	
		s = 0	s = 1	s = 0	s = 1	s = 0	s = 1	s = 0	s = 1	s = 0	s = 1
-0.5	25	11.80	81.34	25.67	69.00	13.94	53.93	39.56	54.80	14.67	24.02
	50	0.02	93.50	0.23	94.65	0.04	67.05	0.95	93.02	0.09	34.69
	75	0.00	93.66	0.00	95.01	0.00	67.72	0.00	93.62	0.00	35.42
	100	0.00	93.57	0.00	94.74	0.00	67.75	0.00	94.22	0.00	35.46
	150	0.00	93.68	0.00	95.19	0.00	68.26	0.00	94.44	0.00	35.94
	200	0.00	93.84	0.00	95.02	0.00	67.81	0.00	94.53	0.00	36.23
	400	0.00	93.90	0.00	94.89	0.00	67.47	0.00	94.45	0.00	35.30
-0.1	25	9.66	83.34	25.67	69.00	13.94	53.93	39.56	54.80	14.67	24.02
	50	0.00	93.56	0.23	94.65	0.04	67.05	0.95	93.02	0.09	34.69
	75	0.00	93.80	0.00	95.01	0.00	67.72	0.00	93.62	0.00	35.42
	100	0.00	93.48	0.00	94.74	0.00	67.75	0.00	94.22	0.00	35.46
	150	0.00	93.56	0.00	95.19	0.00	68.26	0.00	94.44	0.00	35.94
	200	0.00	93.79	0.00	95.02	0.00	67.81	0.00	94.53	0.00	36.23
	400	0.00	93.84	0.00	94.89	0.00	67.47	0.00	94.45	0.00	35.30

Table 6 Performance of TR test
DGP_3 : $r = 1$, $\alpha_1 = -0.5$, $\theta = 0.8$, $\rho_0 = -1$, $\gamma_0 = \{0.5 , 0.1\}$

		Estimated Model									
γ_0	T	Model 1		Model 2		Model 3		Model 4		Model 5	
		s = 0	s = 1	s = 0	s = 1	s = 0	s = 1	s = 0	s = 1	s = 0	s = 1
0.5	25	1.64	48.62	6.78	74.38	19.30	66.47	39.56	54.80	14.67	24.02
	50	0.00	16.40	0.00	50.68	0.05	89.92	0.95	93.02	0.09	34.69
	75	0.00	3.73	0.00	22.13	0.00	91.54	0.00	93.62	0.00	35.42
	100	0.00	0.75	0.00	6.99	0.00	92.73	0.00	94.22	0.00	35.46
	150	0.00	0.01	0.00	0.33	0.00	93.23	0.00	94.44	0.00	35.94
	200	0.00	0.00	0.00	0.00	0.00	93.62	0.00	94.53	0.00	36.23
	400	0.00	0.00	0.00	0.00	0.00	94.38	0.00	94.45	0.00	35.30
0.1	25	12.62	80.31	24.73	69.76	14.26	55.03	39.56	54.80	14.67	24.02
	50	0.05	92.74	0.21	93.58	0.04	69.89	0.95	93.02	0.09	34.69
	75	0.00	92.25	0.00	93.37	0.00	71.93	0.00	93.62	0.00	35.42
	100	0.00	91.19	0.00	92.04	0.00	73.15	0.00	94.22	0.00	35.46
	150	0.00	88.91	0.00	90.46	0.00	76.99	0.00	94.44	0.00	35.94
	200	0.00	86.88	0.00	88.07	0.00	79.15	0.00	94.53	0.00	36.23
	400	0.00	73.95	0.00	77.43	0.00	84.74	0.00	94.45	0.00	35.30

Table 7 Performance of TR test

DGP_4 : $r = 1$, $\alpha_1 = -0.5$, $\theta = 0.8$, $\rho_0 = -1$, $\gamma_0 = 1$, $\rho_1 = \{-0.2 , -0.1\}$

		Estimated Model									
ρ_1	T	Model 1		Model 2		Model 3		Model 4		Model 5	
		s = 0	s = 1	s = 0	s = 1	s = 0	s = 1	s = 0	s = 1	s = 0	s = 1
-0,2	25	0.38	18.12	0.52	64.60	25.31	67.50	39.56	54.80	14.67	24.02
	50	0.00	1.57	0.00	20.23	0.32	94.78	0.95	93.02	0.09	34.69
	75	0.00	0.37	0.00	3.51	0.01	95.91	0.00	93.62	0.00	35.42
	100	0.00	0.12	0.00	0.60	0.00	96.75	0.00	94.22	0.00	35.46
	150	0.00	0.08	0.00	0.01	0.00	97.01	0.00	94.44	0.00	35.94
	200	0.00	0.05	0.00	0.00	0.00	97.21	0.00	94.53	0.00	36.23
	400	0.00	0.00	0.00	0.00	0.00	97.53	0.00	94.45	0.00	35.30
-0,1	25	0.11	13.37	0.10	61.16	21.62	29.96	39.56	54.80	14.67	24.02
	50	0.00	0.26	0.00	12.98	0.12	93.52	0.95	93.02	0.09	34.69
	75	0.00	0.00	0.00	0.79	0.00	94.22	0.00	93.62	0.00	35.42
	100	0.00	0.00	0.00	0.03	0.00	95.11	0.00	94.22	0.00	35.46
	150	0.00	0.00	0.00	0.00	0.00	95.48	0.00	94.44	0.00	35.94
	200	0.00	0.00	0.00	0.00	0.00	95.49	0.00	94.53	0.00	36.23
	400	0.00	0.00	0.00	0.00	0.00	96.00	0.00	94.45	0.00	35.30

3.2 The "Pantula Principle"

In table 8 and table 9 we report the results of several experiments to analyse whether the "Pantula Principle" is a reliable procedure to jointly determine cointegration rank and deterministic components.

Each column in table 8 shows the frequency (%) in which the *Pantula Principle* decides cointegrating rank to be "s", for each of the 5 possible models and DGP. In each row of table 8, the highest frequency appears in bold, showing the cointegrating rank and model selected through the *Pantula Principle*. The procedure consists in testing the hypothesis of cointegrating rank equal zero sequentially from Model 1 to Model 5. If the hypothesis is rejected for each model, then the hypothesis of cointegrating rank equal one is tested, again from Model 1 to Model 5. The procedure stops whenever the first hypothesis is accepted.

Table 8 The *Pantula Principle* performance

DGP_2 : r = 1 , α_1 = -0.5 , θ = 0.8 , ρ_0 = -1

DGP_3 : r = 1 , α_1 = -0.5 , θ = 0.8 , ρ_0 = -1 , γ_0 = 1

DGP_4 : r = 1 , α_1 = -0.5 , θ = 0.8 , ρ_0 = -1 , γ_0 = 1 , ρ_1 = -0.4

DGP	T	s = 0					s = 1				
		M.1	M.2	M.3	M.4	M.5	M.1	M.2	M.3	M.4	M.5
DGP_2	25	20.12	12.14	1.42	14.19	0.63	**47.89**	2.61	0.18	0.36	0.00
	50	1.15	0.19	0.00	0.75	0.01	**91.55**	5.31	0.29	0.52	0.00
	75	0.02	0.00	0.00	0.00	0.00	**93.73**	5.21	0.35	0.41	0.00
	100	0.00	0.00	0.00	0.00	0.00	**93.70**	5.12	0.23	0.59	0.00
	150	0.00	0.00	0.00	0.00	0.00	**93.82**	5.02	0.36	0.44	0.00
	200	0.00	0.00	0.00	0.00	0.00	**93.86**	4.97	0.33	0.44	0.00
	400	0.00	0.00	0.00	0.00	0.00	**93.94**	5.00	0.31	0.40	0.00
DGP_3	25	0.00	0.04	20.61	21.71	0.91	7.54	**24.97**	19.94	3.61	0.00
	50	0.00	0.00	0.05	0.90	0.01	0.15	9.69	**81.51**	6.88	0.00
	75	0.00	0.00	0.00	0.00	0.00	0.00	0.34	**92.38**	6.47	0.00
	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**93.70**	5.51	0.00
	150	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**94.13**	5.16	0.00
	200	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**93.91**	5.48	0.00
	400	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**94.58**	4.98	0.00
DGP_4	25	**51.80**	12.06	17.06	2.34	0.33	13.60	2.20	0.56	0.05	0.00
	50	28.26	11.51	**32.54**	0.04	0.00	19.65	6.12	1.85	0.03	0.00
	75	13.70	7.43	**49.77**	0.00	0.00	19.61	6.58	2.90	0.01	0.00
	100	4.26	3.44	**61.96**	0.00	0.00	18.94	7.33	4.07	0.00	0.00
	150	0.07	0.11	**70.21**	0.00	0.00	18.05	6.32	5.24	0.00	0.00
	200	0.00	0.00	**69.87**	0.00	0.00	17.75	6.61	5.77	0.00	0.00
	400	0.00	0.00	**69.56**	0.00	0.00	17.44	5.32	7.68	0.00	0.00

For DGP_2 and DGP_3 this procedure leads to the correct cointegrating rank, while it takes us to an incorrect specification of deterministic terms in the case of DGP_2. For DGP_4, the *Pantula Principle* not only selects an incorrect cointegrating rank but also take us to a wrong specification of deterministic components.

Table 9 shows the results of the *Pantula Principle* performance, when applied over the two cases to which its use should be restricted to. For DGP_2 and DGP_3, the procedure is applied over Models 2 and 3, while for DGP_4 the *Pantula* Principle is applied over Models 4 and 5.

Table 9 The *Pantula Principle* performance
DGP_2 : r = 1 , α_1 = -0.5 , θ = 0.8 , ρ_0 = -1
DGP_3 : r = 1 , α_1 = -0.5 , θ = 0.8 , ρ_0 = -1 , γ_0 = 1
DGP_4 : r = 1 , α_1 = -0.5 , θ = 0.8 , ρ_0 = -1 , γ_0 = 1 , ρ_1 = -0.4

T	DGP_2				DGP_3				DGP_4			
	s=0		s=1		s=0		s=1		s=0		s=1	
	M.2	M.3	M.2	M.3	M.2	M.3	M.2	M.3	M.4	M.5	M.4	M.5
25	25.67	1.63	**67.48**	0.66	0.04	20.61	**43.82**	28.74	39.56	0.91	**53.92**	0.17
50	0.23	0.00	**94.65**	0.43	0.00	0.05	9.95	**82.28**	0.95	0.01	**93.01**	0.15
75	0.00	0.00	**95.01**	0.52	0.00	0.00	0.34	**92.38**	0.00	0.00	**93.62**	0.10
100	0.00	0.00	**94.74**	0.35	0.00	0.00	0.00	**93.70**	0.00	0.00	**94.22**	0.12
150	0.00	0.00	**95.19**	0.55	0.00	0.00	0.00	**94.13**	0.00	0.00	**94.44**	0.14
200	0.00	0.00	**95.02**	0.44	0.00	0.00	0.00	**93.91**	0.00	0.00	**94.53**	0.06
400	0.00	0.00	**94.89**	0.36	0.00	0.00	0.00	**94.58**	0.00	0.00	**94.45**	0.05

Now, the *Pantula Principle* presents in general good performance. With high probability the procedure detect the correct cointegrating rank and deterministic components specification.

4. Conclusions.

In this paper we have investigated by Monte Carlo simulation, the effect of deterministic parameters misspecification on the performance of Johansen´s likelihood ratio test when determining cointegrating rank in a vector error correction model.

The following results are obtained:

a. The performance of the TR test is poor for low sample sizes, even when the deterministic terms are correctly specified. Sample sizes above 100 are adequate to obtain reliable results.
b. Ignoring the presence of an unrestricted constant in the VECM leads to size distortions with probability of committing a Type I error approaching one for large sample sizes.
c. The omission of linear trend in data generates size distortions, with probability of Type I error equal one. In this case the TR test can lead too often to accept the presence of cointegration.
d. Rank hypothesis testing over Model 2 and Model 4 leads to asymptotic TR test distributions which do not depend on the deterministic parameters of the models.

Thus, cointegration rank can be analysed in this two models separately from deterministic terms.

e. The specification of a model with a restricted trend within the cointegration space and an unrestricted constant (Model 4), seems to be a good option when the correct deterministic term specification is not known.
f. The "Pantula Principle" is not a reliable procedure to jointly determine cointegration rank and deterministic components, when applied on the five possible cases.

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ANNEX I. REVIEW OF ELG EMPIRICAL LITERATURE

TABLE A1. Estudios empíricos de series temporales de causalidad, cointegración y modelos de corrección del error

Estudio	Muestra	Variables		Metodología	Conclusiones (1)
		crecimiento	exportaciones		
Afxentiou y Sereletis (1991)	16 países desarrollados 1950-1985	*LnPNB* real	*LnEX* real	(i) Phillips-Perron (con constante y sin constante) (ii) Engle-Granger (Durbin-Watson, Phillips-Perron sin constante) (iii) Granger: VAR en primeras diferencias para los casos sin cointegración, y MCEV para los casos en los que hay cointegración	Cointegración en 3 países (Islandia, Noruega y los Países Bajos) $Y \Rightarrow X$ en 3 países (Canadá, Japón y Noruega) $X \Leftrightarrow Y$ en 1 país (Estados Unidos) No hay una relación clara entre exportaciones y renta en los países desarrollados.
Kugler (1991)	6 países desarrollados (Alemania occidental, Estados Unidos, Francia, Japón, Reino Unido y Suiza) 1970-87 (trimestral, desestacionalizada)	*LnPIB*	*LnEX*	(i) Dickey-Fuller Aumentado (con constante, r= 1 y 6) (ii) Johansen (r=3,5,6, CIA) Otras variables: consumo e inversión	Cointegración entre exportaciones y el resto de variables sólo en el caso de Alemania occidental y Francia.
Marin (1992)	4 países desarrollados (Alemania, Estados Unidos, Japón y Reino Unido) 1960:I-1987:II	Ln de la productividad del trabajo	*LnEX* de manufacturas	(i) Dickey-Fuller Aumentado (sin constante, r= 0 y 4) (ii) Engle-Granger (Durbin-Watson, Dickey-Fuller Aumentado) (iii) Granger-Sargent: VAR en primeras diferencias y MCEV. Otras variables: ratio exportaciones sobre importaciones en valor unitario, renta de los países de la OCDE	Cointegración salvo en el Reino Unido cuando se incluyen todas las variables. No cointegración en ningún caso cuando se incluyen sólo exportaciones y renta. $X \Rightarrow Y$ en los cuatro países
Serletis (1992)	Canadá 1870-1985 (dos subperiodos 1870-1944, 1945-1985)	*LnPNB*	*LnEX*	(i) Phillips-Perron (sin constante, con constante, con constante y tendencia, r=0,2,4, 6,8,10,12) (ii) Engle-Granger (iii) Granger-Sargent: VAR en primeras diferencias (CS) Otras variables: importaciones	No hay cointegración. $X \Rightarrow Y$ en los periodos analizados. También se encuentra causalidad unidireccional de las exportaciones hacia las importaciones.

Notas: (1) $Y \Rightarrow X$ causalidad de la renta hacia las exportaciones, $X \Rightarrow Y$ causalidad de las exportaciones hacia la renta, $X \Leftrightarrow Y$ causalidad bidireccional.
Fuente: Elaboración propia.

TABLE A1. Estudios empíricos de series temporales de causalidad, cointegración y modelos de corrección del error (continuación)

Estudio	Muestra	Variables		Metodología	Conclusiones (1)
		crecimiento	exportaciones		
Giles *et al* (1992)	Nueva Zelanda 1963-1991	*LnPIB* real	7 categorías de exportaciones sobre el total y exportaciones totales sobre el PIB (variables en ln y reales)	(i) Dickey-Fuller Aumentado (sin constante, con constante, con constante y tendencia, r entre 0 y 5) (ii) Engle-Granger (Dickey-Fuller Aumentado) (iii) Granger-Sargent, Granger-Hsiao: VAR en niveles y MCEV en los casos en los que hay cointegración. VAR en primeras diferencias en el resto de casos.	Cointegración sólo para exportaciones de animales vivos (categ. 1) y de bienes manufacturados (categ. 5). $X \Rightarrow Y$ en los periodos en animales vivos (categ. 1), minerales, productos químicos y plásticos (categ. 4), bienes manufacturados (categ. 5) y metales (categ. 6)
Oxley (1993)	Portugal 1865-1985	*LnPIB* real	*LnEX* real	(i) Dickey-Fuller Aumentado (con constante, con constante y tendencia, r=4) (ii) Johansen (r=3) (iii) Granger-Sargent (EPF)	Cointegración entre exportaciones y renta. $Y \Rightarrow X$
Kugler y Didri (1993)	11 países en desarrollo 1960-1989	*LnPIB*	*LnEX*	(i) Dickey-Fuller Aumentado (con constante y tendencia, r=1,2) (ii) Johansen (CIA) Otras variables : consumo e inversión	Cointegración entre exportaciones y el resto de variables en 7 países (Argentina, Brasil, Chile, Hong kong, Corea del Sur, Pakistán, Islas Filipinas y Tailandia)
Van Den Berg y Schmidt (1994)	17 países de América Latina 1960-87	$(\Delta PIB / PIB)$ real	$(\Delta EX / EX)$ real	(i) Phillips-Perron (con constante, con constante y tendencia, r=3), KPSS (con constante, con constante y tendencia) (ii) Engle-Granger (Phillips-Perron) (iii) MCEV y modelos uniecuacionales para la renta en tasas de crecimiento Otras variables : ratio inversión-PIB y trabajo	Cointegración en Guatemala, México y Nicaragua. Relación significativa y positiva entre exportaciones y renta en 12 países.
Ahmad y Harnhirun (1995)	5 países asiáticos (Indonesia, Islas Filipinas, Malasia, Singapur y Tailandia) 1966-1990	*LnPIB* real	*LnEX* real	(i) Dickey-Fuller Aumentado (con constante y tendencia) (ii) Johansen (iii) Granger-Sargent: MCEV (sólo se contrasta causalidad en el caso de Singapur)	Cointegración sólo en el caso de Singapur. $X \Leftrightarrow Y$ en Singapur

Notas: (1) $Y \Rightarrow X$ causalidad de la renta hacia las exportaciones, $X \Rightarrow Y$ causalidad de las exportaciones hacia la renta, $X \Leftrightarrow Y$ causalidad bidireccional.
Fuente: Elaboración propia.

TABLE A1. Estudios empíricos de series temporales de causalidad, cointegración y modelos de corrección del error (continuación)

Estudio	Muestra	Variables: crecimiento	Variables: exportaciones	Metodología	Conclusiones (1)
Jin (1995)	4 países asiáticos (Corea del Sur, Hong Kong, Singapur y Taiwán) 1973:I-1993:II	$LnPIB$ real	$LnEX$ real	(i) Dickey-Fuller Aumentado (con constante y tendencia, r=4) (ii) Engle-Granger (Dickey-Fuller Aumentado) (iii) Descomposición de la varianza y función de respuesta al impulso Otras variables: tipo de cambio real, renta externa, variables indicadoras de shocks en precios.	No hay cointegración. Relación de *feedback* positiva y significativa en los cuatro países en el corto plazo.
Thornton (1996)	México 1895-1992	$LnPIB$ real	$LnEX$ real	(i) Dickey-Fuller Aumentado (ii) Johansen (r=4) (iii) Granger-Sargent: MCEV	Cointegración $X \Rightarrow Y$
Thornton (1997)	6 países europeos (Alemania, Dinamarca, Italia, Noruega, Reino Unido y Suecia) 1850-1913	$LnPNB$ real	$LnEX$ real	(i) Dickey-Fuller Aumentado (con constante y tendencia) y Phillips-Perron (ii) Johansen (CIA) (iii) Granger-Sargent: MCEV (EPF) Otras variables: tasa arancelaria media.	Cointegración salvo en el caso de Suecia. $X \Rightarrow Y$ en Italia, Noruega y Suecia. $Y \Rightarrow X$ en Reino Unido. $X \Leftrightarrow Y$ en Alemania y Dinamarca.
Ghatak *et al* (1997)	Malasia 1955-1990	$LnPIB$ y $LnPIB$ neto de exportaciones en términos reales	$LnEX$ (total, productos primarios, productos energéticos) real	(i) Dickey-Fuller Aumentado (con constante, r=1,2) (ii) Engle-Granger (Dickey-Fuller Aumentado) y Johansen (iii) Granger-Sargent: MCEV (EPF) Otras variables: stock de capital físico y stock de capital humano.	Cointegración $X \Rightarrow Y$
Liu *et al* (1997)	China 1983:III-1995:I	$LnPNB$ real	$LnEX$ real LnM real $Ln(EX + M)$ real	(i) Dickey-Fuller Aumentado (con constante y tendencia, r=5-10) (ii) Engle-Granger (Dickey-Fuller Aumentado) (iii) Granger-Sargent, Sims, Granger-Hsiao.	No hay cointegración. Relación de *feedback* positiva y significativa entre la renta y la variable exportaciones más importaciones.
Ramos (2001)	Portugal 1865-1998	$LnPIB$ real	$LnEX$ real LnM real	(i) Dickey-Fuller Aumentado y Phillips-Perron (ii) Johansen (CIA) (iii) MCEV	2 relaciones de cointegración entre renta, exportaciones e importaciones. Causalidad bidireccional entre las exportaciones y la renta y entre las importaciones y la renta.

Notas: (1) $Y \Rightarrow X$ causalidad de la renta hacia las exportaciones, $X \Rightarrow Y$ causalidad de las exportaciones hacia la renta, $X \Leftrightarrow Y$ causalidad bidireccional.
Fuente: Elaboración propia.

ANNEX II. THE DATA GENERATION PROCESS

The starting point of our different DGP is a bivariate VAR model of order one,

$$\underbrace{\begin{pmatrix} X_{1t} \\ X_{2t} \end{pmatrix}}_{X_t} = \underbrace{\begin{pmatrix} \mu_{01} \\ \mu_{02} \end{pmatrix}}_{\mu_0} + \underbrace{\begin{pmatrix} \mu_{11} \\ \mu_{12} \end{pmatrix}}_{\mu_1} t + \underbrace{\begin{pmatrix} \alpha_1 + 1 & -\alpha_1 \\ 0 & 1 \end{pmatrix}}_{\Phi} \underbrace{\begin{pmatrix} X_{1t-1} \\ X_{2t-1} \end{pmatrix}}_{X_{t-1}} + \underbrace{\begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{pmatrix}}_{\varepsilon_t} \qquad (1.17)$$

where $\varepsilon_t \sim$ iid $N(0 , \Sigma_\varepsilon)$ and,

$$\Sigma_\varepsilon = \begin{pmatrix} 2\theta + 2 & \theta + 1 \\ \theta + 1 & 1 \end{pmatrix} \qquad (1.18)$$

The eigenvalues of matrix Φ are $\lambda_1 = 1$ and $\lambda_2 = 1 + \alpha_1$ so that for $\alpha_1 \in [-2 , 0]$ we have that $|\lambda_2| < 1$. Matrix Φ can be descomponed in the following way,

$$\Phi = C\Lambda C^{-1} = \begin{pmatrix} c_{11} & c_{12} \\ c_{21} & c_{22} \end{pmatrix} \begin{pmatrix} 1 & 0 \\ 0 & 1+\alpha_1 \end{pmatrix} \begin{pmatrix} c_{(1)1} & c_{(1)2} \\ c_{(2)1} & c_{(2)2} \end{pmatrix} = (C_1 , C_2) \begin{pmatrix} 1 & 0 \\ 0 & 1+\alpha_1 \end{pmatrix} \begin{pmatrix} C'_{(1)} \\ C'_{(2)} \end{pmatrix} \qquad (1.19)$$

where C_1 and C_2 are the asociated lineally independent eigenvectos[5]. It is possible to rewritte the VAR(1) model in (5.24) as,

$$\underbrace{C^{-1}X_t}_{Z_t} = \underbrace{C^{-1}\mu_0}_{\mu_{C0}} + \underbrace{C^{-1}\mu_1 t}_{\mu_{C1}t} + \underbrace{C^{-1}\Phi C}_{\Lambda} \underbrace{C^{-1}X_{t-1}}_{Z_{t-1}} + \underbrace{C^{-1}\varepsilon_t}_{U_t} \qquad (1.20)$$

where,

$$\begin{pmatrix} Z_{1t} \\ Z_{2t} \end{pmatrix} = \begin{pmatrix} C'_{(1)} X_t \\ C'_{(2)} X_t \end{pmatrix} = \begin{pmatrix} C_{(1)1} X_{1t} + C_{(1)2} X_{2t} \\ C_{(2)1} X_{1t} + C_{(2)2} X_{2t} \end{pmatrix} \qquad (1.21)$$

or,

[5] This two eigenvectors are not unique. In our case, and due to the fact that $\lambda_1 = 1$ y $\lambda_2 = (1 + \alpha_1)$, we have $C_1=\{(c_{11} , c_{21})' \,/\, c_{11} = c_{21}\}$ y $C_2=\{(c_{12} , c_{22})' \,/\, c_{22} = 0\}$.

$$\begin{pmatrix} Z_{1t} \\ Z_{2t} \end{pmatrix} = \begin{pmatrix} \mu_{C01} \\ \mu_{C02} \end{pmatrix} + \begin{pmatrix} \mu_{C11} \\ \mu_{C12} \end{pmatrix} t + \begin{pmatrix} 1 & 0 \\ 0 & 1+\alpha_1 \end{pmatrix} \begin{pmatrix} Z_{1t-1} \\ Z_{2t-1} \end{pmatrix} + \begin{pmatrix} U_{1t} \\ U_{2t} \end{pmatrix} \tag{1.22}$$

where $U_t \sim$ iid $N(0\ ,\ C^{-1}\Sigma_\varepsilon C^{-1'})$. Now we have that $\Delta Z_{1t} = \mu_{C01} + \mu_{C11}t + U_{1t}$ and $(1-(1+\alpha_1)B)Z_{2t} = \mu_{C02} + \mu_{C12}t + U_{1t}$. Z_{1t} is I(1), a random walk with drift and trend, and for $\alpha_1 \in [-2\ ,\ 0]$ we have that Z_{2t} is I(0). The variables X_{1t} y X_{2t} are a lineal combination of a I(1) variable and a I(0) variable so that they are both I(1). From (5.29) $Z_{2t} = C'_{(2)} X_t = c_{(2)1}X_{1t} + c_{(2)2}X_{2t}$, so that ($C'_{(2)} X_t$) is I(0) and $X_t \sim CI(1,1)$ with cointegrating vector $\beta \equiv (\beta_1\ ,\ \beta_2)' = C_{(2)} \equiv (c_{(2)1}\ ,\ c_{(2)2})'$. For $C_1 = (1\ ,\ 1)'$ and $C_2 = (1\ ,\ 0)'$, matrix Σ_U is,

$$\Sigma_U = C^{-1}\Sigma_\varepsilon (C^{-1})' = \begin{pmatrix} 1 & \theta \\ \theta & 1 \end{pmatrix} \tag{1.23}$$

The θ parameter is the correlation coefficient between the two components of the process, the stationary one (Z_{2t}) and the nonstationary (Z_{1t}). For $\theta = 0$ the components in (5.29) are independent and for $\theta \neq 0$ they are contemporaneously correlated. Similar models to that in (5.29) and (5.30) have been used in several works as in Toda (1994), Toda (1995) and Hubrich *et al* (2001). The DGP used in the present work, are based in (5.24). That is a vector error correction model (VECM),

$$\underbrace{\begin{pmatrix} \Delta X_{1t} \\ \Delta X_{2t} \end{pmatrix}}_{\Delta X_t} = \underbrace{\begin{pmatrix} \mu_{01} \\ \mu_{02} \end{pmatrix}}_{\mu_0} + \underbrace{\begin{pmatrix} \mu_{11} \\ \mu_{12} \end{pmatrix}}_{\mu_1} t + \underbrace{\begin{pmatrix} \alpha_1 & -\alpha_1 \\ 0 & 0 \end{pmatrix}}_{\Pi} \underbrace{\begin{pmatrix} X_{1t-1} \\ X_{2t-1} \end{pmatrix}}_{X_{t-1}} + \underbrace{\begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{pmatrix}}_{\varepsilon_t} \tag{1.24}$$

where $\Pi \equiv \Phi - I$. The rank "r" of matrix Π, is the cointegration rank among the components of vector X_t. We can now decompose matrix Π as the product of two matrices,

$$\Pi = C(\Lambda - I)C^{-1} = (C_1\ , C_2) \begin{pmatrix} 0 & 0 \\ 0 & \alpha_1 \end{pmatrix} \begin{pmatrix} C'_{(1)} \\ C'_{(2)} \end{pmatrix} = [C_2\alpha_1][C'_{(2)}] = \alpha\beta' \tag{1.25}$$

Again for $C_1 = (1\ ,\ 1)'$ and $C_2 = (1\ ,\ 0)'$, we have that $\alpha = (\alpha_1\ ,\ 0)'$ y $\beta = (1\ ,\ -1)'$.