

Common trends in producers' expectations, the nonlinear linkage with Uruguayan GDP and its implications in economic growth forecasting*

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Common trends in producers' expectations, the nonlinear linkage with Uruguayan GDP and its implications in economic growth forecasting

Bibiana Lanzilotta (*)(**), Juan Gabriel Brida(**), Lucía Rosich (*)(**)

Resumen

Este trabajo estudia las tendencias comunes entre las expectativas de los productores industriales y su interdependencia con el crecimiento económico del Uruguay en las últimas dos décadas (1998 – 2017).

Se utilizaron las series de expectativas recabadas por la Cámara de Industrias del Uruguay clasificadas en cuatro grupos industriales: exportadoras, bajo comercio, sustitutivas de importación y comercio intra rama. En base a la estimación de Modelos Estructurales Multivariantes, se encontró un nivel común entre los indicadores de expectativas de los cuatro grupos industriales. El grupo que lidera las expectativas de todas las empresas pertenecientes a la industria manufacturera es el más expuesto a la competencia internacional. En consecuencia, el componente tendencial de las empresas exportadoras impulsa al de los otros grupos.

Palabras clave: expectativas de los agentes, factores comunes, Modelos Estructurales Multivariantes, proyección del PIB, cointegración no lineal.

Código JEL: C32, D84, E32

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Abstract

This paper examines the common trends between producers' expectations and their interdependence with economic growth in Uruguay, for the last two decades (1998-2017).

We consider producers' expectation indicators derived from qualitative surveys collected by the "Cámara de Industrias del Uruguay" classified in four groups: exporters, low-trade industries, import-substitution industries and intra-sectoral trade industries. In base on Multivariate Structural Models estimations, we found that there is a common level between the expectation indicators of four manufacturing groups. The group who lead expectations of all manufacturing firms is the more exposed to international competition. So, the trend component of the expectations drives that of the other groups.

The research additionally shows that there is a nonlinear cointegration relationship between producers' expectations and Uruguayan GDP growth. Although it indicates that in the long-run there is bidirectional causality between both variables, in the shortrun causality goes uniquely from expectations to GDP growth. Besides, this finding suggests that expectations could be an accurate leader indicator; the driver of the global expectation is the aggregate indicator of the more tradable manufacturers in Uruguay.

Keywords: agents' expectations, common factors, Multivariate Structural Models, GDP forecasting, nonlinear cointegration.

JEL Classification: C32, D84, E32

1. Introduction

Both theory and applied research have shown the importance of expectations concerning economic fundamentals and cyclical fluctuations. According to these studies, macroeconomic fluctuations are not only a product of the current economic situation but are also very frequently influenced (and stressed) by agents' expectations. Several and recent empirical studies have shown this fact (Karnizova, 2010; Leduc & Sill, 2010; Patel, 2011; Conrad & Loch, 2011).

Expectation indicators developed from opinion surveys among agents (entrepreneurs, consumers or experts), are nowadays widely used, essentially, because of their predictive power of the main macroeconomic variables (see among others, Svensson, 1997; Berk, 1999; Pesaran, Pierse & Lee, 1993; Rahiala & Teräsvirta, 1993; Smith & McAleer, 1995; Kauppi, Lassila & Teräsvirta, 1996; Öller, 1990; Hanssens & Vanden Abeele, 1987; Alfarano & Milakovic, 2010; Clavería, 2010; Clavería et al. 2006; 2007; 2015; 2016; 2017). In their extensive review of this empirical literature, Pesaran & Weale (2006) show that different approaches have been used to address many of these issues.

Authors such as Beaudry & Portier (2006) have found that in the US economy, share prices are predictors of total factor productivity growth and financial booms are accompanied by a broad economic expansion. Karnizova (2010) proposed a model to explain fluctuations caused by expectations, incorporating what she calls the intrinsic desire for wealth accumulation. Eusepi & Preston, 2008 developed a theory of fluctuations driven by expectations based on learning, with agents possessing incomplete information. Using a neoclassical model, Floden (2007) has shown that excessive optimism about future productivity can lead to immediate economic expansions (on the assumption of variable capacity utilization). Li & Mehkari (2009) presented a model incorporating endogenous product creation, and Patel (2011) has studied the effect of investors' expectations on their investment decisions, finding that they are particularly important in contexts of poor-quality or limited information on assets.

Meanwhile, authors such as Eusepi & Preston (2008), have shown the potential of disaggregated analysis for research into the genesis of cyclical fluctuations, focusing on the role of information disparities between agents linked by the production chain. Others (Long &Plosser, 1983; Blanchard, 1987; Durlauf, 1991; Caballero & Lyons, 1990) have emphasized various mechanisms whereby sectoral interactions in the formation of expectations —such as the build-up of small menu costs, disjointed decision-making and coordination failures— influence macroeconomic dynamics. Beaudry & Portier (2007) argue that although expectations are often singled out as a factor that contributes to explain fluctuations, interactions can only be observed from a disaggregated sectoral analysis, i.e., a more detailed representation of the economy than macroeconomic

models can provide. This influence arises because of production complementarities between the various sectors of the economy.

In the same line, Lee & Shields (2000) proposed (following Lee & Pesaran, 1994; Lee, 1994; and Lee, Pesaran & Pierse, 1992), an intersectoral VAR model for industrial production in the United Kingdom which uses direct measurements of expectations (gathered by the Confederation of British Industry). The authors found that these data provided invaluable information on the role of expectations and could be used to identify the sources of persistent effects from shocks and the mechanisms whereby these effects were transmitted across sectors and over time.

Although there is vast international empirical literature, little research has been done on this subject in Uruguay. Because it is a small, open country, its economy has traditionally been subject to external shocks, particularly from its neighbours Argentina and Brazil. Those shocks have brought about strong cyclical fluctuations and episodes of crisis.

The present paper analyses the importance of agents' expectations (industrialists' expectations) in predicting GDP growth, based on previous studies for Uruguay (Lanzilotta, 2006; 2015).

This paper takes a predominantly empirical and exploratory approach. It examines the influence of Uruguayan industrialists' expectations on economic performance, breaking down the sector into four groupings differentiated by their trade participation and production specialization. To examine the relationship between the expectations of these four industry groups we seek to identify common underlying trends between them. To this aim, following several studies (such as Carvalho & Harvey, 2005, and Carvalho et al., 2007) we estimate a multivariate structural time series model (Engle & Kozicki, 1993; Vahid & Engle, 1993) and identify the driver within this expectation. Finally, by applying the procedure proposed by Breitung (2001) and Holmes & Hutton we test the existence of a long-run relationship between producers' expectations the Uruguayan GDP growth.

The findings show that there is a common trend between industrialists' expectations. This common trend is identified with the one guiding the evolution of expectations in the export-oriented grouping, and expectations in the other groups depend on it. Additionally, this trend has a nonlinear cointegrated relationship with the Uruguayan GDP growth, which confirms the important role of the expectations of industrialists most exposed to international competition in the forecasting of economic growth. Therefore, the study revealed the influence of producers' expectations on overall economic activity, showing that the information they provided could be useful for predicting and anticipating cyclical fluctuations in Uruguay and are a valuable input for predicting the overall activity growth.

The empirical analysis makes use of the expectation measurements collected by the Chamber of Industry of Uruguay (CIU)¹ and industrial production indicators from the Monthly Survey of Manufacturing Industry conducted by the National Institute of Statistics (INE). Monthly data from January 1998 to July 2011 are considered.

The remainder of the document is organized as follow. The next section describes the data and the methodological framework. Section three shows the empirical results, and in the last section, we conclude and discuss the policy implications.

2. Data and methodological framework

The information on producers' expectations comes from the monthly industrial surveys conducted by the CIU since 1997. This survey asks entrepreneurs of the manufacturing sector, about their expectations on the national economy (among other dimensions) for the next 6 months. They are asked to state whether they expect the situation to improve, worsen or remain the same.² Results of the expectation survey is public available 45 days after the reference month of the survey.

In their review of the literature on the use of expectations data, Pesaran & Weale (2006) stress two crucial aspects: the way that responses are gathered and the way that they are converted into aggregate quantitative data. Remond-Tiedrez (2005), also has an interesting discussion of this issue. This paper has attempted to deal with both aspects.

As Pesaran & Weale state, a key feature to be considered is the method of aggregation of expectation responses. In the monthly CIU survey, respondents from each company are asked the following question: "In view of the current situation, how do you expect the national economy, your sector and your company to perform in the next six months?" In this paper, the balance statistic method is used to aggregate the responses. This procedure is employed by Eurostatand is routinely used in applied studies on the subject (Kangasniemi, et al., 2010, and Kangasniemi & Takala, 2012). This methodology involves the construction of aggregate indicators of expectations by subtracting the number of negative responses. Each response is accorded equal weight in the indicator regardless of the size of the company or the branch of activity in which it operates.

To resume the expectation responses, we construct balance indicators for four groups of manufacturing firms. The classification in four groups follows Laens & Osimani (2000), who propose classify manufacturing industries according to the patterns of trade and production specialization of the firms, considering the import and export flows and

¹<u>http://www.ciu.com.uy/innovaportal/v/15128/9/innova.front/expectativas-empresariales-industriales.html</u>

²The good fit between the CIU and official data of manufacturing sales provides reassurance that there are no serious sampling errors. Nonetheless, problems of framing or strategic bias could in principle be an issue.

domestic production.³ They classified 73 sectors (disaggregated at the four-digit level of ISIC revision 2) into four groups: exporter industries, low-trade industries, importsubstitution industries and intra-sectoral trade industries. This classification criterion ensures that growth determinants act in a reasonably homogeneous way within each group. As Lorenzoet al.(2003) state, breaking industry down into homogeneous groups enhances the diagnosis since sectoral specificities are manifested in clearly differentiated patterns of behaviour.

In addition to the indicators of expectations discussed above, this paper also considers Real Gross Domestic Product (GDP) of the Uruguayan economy. The data analysed in this study concern the period from January 1998 to December 2017, with quarterly frequency and is represented in Figure 1.

Figure 1. Expectation indicators (left panel) and Uruguayan GDP growth (right panel). 1998.Q1-2017.Q4



Source: based on CIU and BCU. Note: exp_x= exporter industries' expectations, exp_lt=low-trade sector' expectations, exp_ic=intra sectorial commerce industries' expectations, exp_m=import substitution industry' expectations.

The methodological framework for the empirical analysis is based on the estimation of structural time series models (Koopman et al., 2009) and cointegration analysis. The basis for identifying common trends between time series is the application of multivariate structural models. The methodological framework for identifying common trends and (more generally)common factors was developed by Engle & Kozicki (1993)

³ Sectors with an openness ratio (exports plus imports as a share of overall output) of under 5% are categorized asa *low-trade* group. Sectors with an openness ratio of over 5% are then analysed for intraindustry trade using the relevant Grubel-Lloyd indices. Industries with a Grubel-Lloyd index value of over 0.50 are classified as an intra-industry trade group. Those with Grubel-Lloyd scores of less than 0.50 are then separated according to whether their sectoral trade balance is positive or negative, sectors with a positive trade balance being classed as exporters and those with a negative balance as importsubstitution industries.

and Vahid & Engle (1993) and applied in several studies, such as Carvalho & Harvey (2005) and Carvalho, et al. (2007). The tests for identifying common trends in a multivariate structural model were developed by Nyblom & Harvey (2001).

In addition, in order to analise the role of expectations have a relevant role in GDP forecasting we analysed the existence of a cointegration relationship between the underlying trend of industrial expectations and the Uruguayan GDP growth ($\Delta_4 \ln$ GDP)by applying a set of 'free models' (following Breitung, 2001, and Ye Lim et al., 2011). This procedure allows testing the existence of cointegration and also the linearity of the underlying relationship between the cointegrated variables.

Specifically, Breitung (2001) proposed a rank transformation for the series involved and 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 *score statistic* $(T \cdot R^2)$. A more detailed description of these tests is included in Annex.

3. Results

The graphical analysis of the expectation indicators (Figure 1, left panel) of the four industry groups evidences that they have a similar evolution, and suggest the existence of a common trend between them. In order to identify the common factor between them we estimate a multivariate structural model (Engle & Kozicki, 1993; Vahid & Engle, 1993). In accordance with the characteristics of the four series, we initially formulate an unrestricted specification of a local level model with drift:

$$\exp_{i_{t}} = \alpha_{i} + \mu_{it} + \epsilon_{it}, \ \epsilon_{it} \sim \text{NIID}\left(0, \sigma_{i\epsilon}^{2}\right), \ t = 1, \dots, T, i = x, lt, ic, m$$

$$\mu_{it} = \mu_{it-1} + \eta_{it}, \qquad \eta_{it} \sim \text{NIID}(0, \sigma_{in}^{2}),$$
(1)

where μ_t is the underlying level, and ϵ_t and η_t are white noise disturbance, both normally distributed and independent of each other. Additionally the model present an autorregresive component in order to correct for autocorrelation of the process and qualitative variables were also included for outliers' correction. The results are presented in Table 1.

Table 1. Unrestricted multivariate structural model (UnModel). Vector of endogenous variables: [exp_x, exp_lt, exp_ic, exp_m].

Model estimated:				
Y = Level + Irregular + Cycle + AR(1) (strong	exp_x	exp_lt	exp_ic	exp_m
convergence)				
I. Standard deviations of the component residues:				
Irregular	0.0183213	0.0168855	0.03906136	0.0315031
Level	0.1435112	0.1253643	0.11070953	0.1072958
Cycle	-	-	-	-
AR(1)	0.0442764	0.04725177	0.09790924	1.0244137
				5
AR coefficient	0.61585	0.86513	0.56430	0.12878
II. Model diagnostic statistics:				
Normality (Bowman-Shenton)	5.8586	7.4957	2.5458	7.6502
Т	72	73	70	73
Rd^2	0.27656	0.21453	0.27642	0.34623
Courses our une coordine				

Quarterly data, 1998QI - 2017Q.IV

Source: own processing.

a A full list of outputs is available from the author on request.

Note: exp_x: expectations of export industries; exp_m: expectations of import-substitution industries; exp_ic: expectations of intra-sectoral trade industries; *iec_lt*: expectations of low-trade industries. AR(1): autoregressive process (order = 1).

The model's variance-covariance matrix shows a high correlation between the levels of the expectation series (Table 2) which suggests the existence of common trends.

Table 2. Variance-covariance matrix of the residuals of the unrestricted multivariate model

	exp_x	exp_lt	exp_ic	exp_m
exp_x	0.0206	0.9724	0.9053	0.9823
exp_lt	0.0175	0.01572	0.9495	0.9951
exp_ic	0.01438	0.01318	0.01226	0.9631
exp_m	0.01513	0.01339	0.01144	0.01151

Source: prepared by the author.

Note: exp_*x*: expectations of export industries; exp_*m*: expectations of import-substitution industries; exp_*ic*: expectations of intra-sectoral trade industries; *iec_lt*: expectations of low-trade industries. Grey shading denotes significant values.

The analysis of variance/correlation matrix suggest that the matrix rank is 1 (2 at a lower significance level). This justified the restriction of common levels between the series which is consistent with the preliminary graphical analysis.

In accordance with the eigenvalues of the matrix of variances, the expectations series for intra-sectoral trade, low-trade and import-substitution industries were specified as dependent. The results are presented in Table 3 and Figure 2.

Table 3. Restricted multivariate structural model with common trends. Vector of endogenous variables: [exp_x, exp_lt, exp_ic, exp_m].

Model estimated:				
Y = Level + Irregular + Cycle + AR(1) (strong	exp_x	exp_lt	exp_ic	exp_m
_convergence) exp_lt, exp_ic, exp_m: dependent				
I. Standard deviations of the component residues:				
Irregular	0.0075090	0.0180425	0.0511940	0.0249947
Level	0.0399903	-	-	-
Cycle	-	-	-	-
AR(1)	0.1406744	0.1179466	0.1192950	0.0954226
				4
II. Model diagnostic statistics:				
Normality (Bowman-Shenton)	3.6559	6.4634	1.5909	5.4138
Т	72	73	70	73
Rd^2	0.33485	0.26135	0.2985	0.42233
C				

Quarterly data, 1998.I - 2017.IV

Source: own processing.

a A full list of outputs is available from the author on request.

Note: exp_x: expectations of export industries; exp_m: expectations of import-substitution industries; exp_ic: expectations of intra-sectoral trade industries; iec_lt: expectations of low-trade industries. AR(1): autoregressive process (order = 1).

Figure 2. Components of the multivariate structural model with common trends, 1998Q1-2017Q4

(Index values)



Source: own processing.

The model estimated (ignoring cyclical and autoregressive components) can be written as:

$$\begin{split} & \exp \ _x_t = \mu_{t_{,}}^* + \ \epsilon_{\exp \ _xt}, \\ & \exp \ _lt \ _t = 1.384 \mu_{t_{,}}^* + 0.03994 + \epsilon_{\exp \ _ltt} \,, \end{split}$$

$$\begin{split} & \exp_{i} c_{t} = 1.865 \mu_{t_{j}}^{*} + 0.2439 + \epsilon_{\exp_{i} ct}, \\ & \exp_{m_{t}} = 1.215 \mu_{t_{j}}^{*} - 0.1556 + \epsilon_{\exp_{m_{t}} mt}, \end{split}$$

where μ_t^* is a univariate random walk with drift. Therefore the level components have the following relationship:

$$\mu_{\exp _lt_t} = 1.384 \,\mu_{\exp _x_t_i} + 0.03994,$$
$$\mu_{\exp _ic_t} = 1.865 \mu_{\exp _x_t_i} + 0.2439,$$
$$\mu_{\exp _m_t} = 1.215 \mu_{\exp _x_t} - 0.1556,$$

where the common trend is the one estimated for export industries: $\mu_{exp} \,_x_t$

As we stated, previous international (Kangasniemi et al. (2010); Kangasniemi & Takala, 2012) and local research (Lanzilotta, 2015) allows as hypothesizing that expectations have a relevant role in GDP forecasting. To prove this, we analysed the existence of a cointegration relationship between the underlying trend of industrial expectations and the Uruguayan GDP growth($\Delta_4 \ln$ GDP)by applying a set of 'free models' (following Breitung, 2001, and Ye Lim et al.,2011). As is was explained before, Breitung propose testing the existence of cointegration without imposing any parametric model. When cointegration is accepting, this author proposed testingthe linearity of the underlying relationship between the cointegrated variables.

Results of cointegration and non-linearity test are shown in Table 4.

Table 4	Results	of non	parametric	cointegration	test and	linearity	test

	Test Statistics				
	$\Xi_{\mathrm{T}}^{*}[1]$	$T \cdot R^2$			
[0.0175**	7.4689***			
$\mu_{\exp x_t} \Delta_4 \ln GD$					
Significance	Critical values				
Level					
10%	0.025	2.706			
5%	0.020	3.841			
1%	0.014	6.635			

Notes: The hypothesis of no cointegration is rejected if the rank statistic, Ξ_T^* [2], is below the respective critical value and the hypothesis of linearity is rejected if the score statistic, $T \cdot R^2$, exceeds the χ^2 critical values. *, ** and *** denote significance at 10%, 5%, according with the grades of freedom of each estimation.

According to the results, we can reject non-cointegration hypothesis and linearity. Therefore, results suggest that exists a long-run relationship between Uruguayan GDP growth and expectations (the underlying trend of industrial expectations), which is nonlinear.

Finally, we examine causality between the variables applying the nonparametric procedure proposed in Holmes & Hutton (1990). This test is more robust than conventional parametric tests usually applied (see Annex 3 for a more detailed explanation of this test). Results are shown in Table 5.

H-H causality test. ——	Urugu	ay
H0 nc	Probability	NC
d(exp)>d2(lGDP)	0.000	Α
d2(lGDP)>d(exp)	0.143	R
exp>d4lGDP	0	Α
d4lGDP>exp	0	Α

Table 5. . Results of nonparametric causality test

Notes: F-statistic, NC: H0: noncausality

Results confirm the bidirectional causality between Uruguayan GDP growth and expectations (the underlying trend of industrial expectations) when the test is performed in levels (i.e. for the long run). However, in the short-run (that is when the H-H causality test is run in first differences of the variables) the evidence uniquely allows accepting causality from expectation to GDP growth.

4. Main conclusions

This paper provides evidence on some aspects of the formation of industrialists' expectations and sheds light on how these ultimately relates to GDP growth. Two main findings emerge from this research.

Firstly, the results indicate that Industrialists' expectations (grouped into four classes according to their specialization and international insertion) follow a single common trajectory, which is determined by expectations in the export group. This finding shows the importance of export industries in spreading macroeconomic expectation shocks.

The key role played by the most trade-oriented industries is associated with the importance of this group in the Uruguayan manufactured production. Export industries account for over 50% of industrial production (excluding the oil refinery) and have significantly backwards spillover effect (because production inputs are primarily national). Besides their representativeness, their exposure to international trade makes them more competitive and provides them with access to extensive and complete information on the relevant macroeconomic and international context. Learning hypothesis postulated by Eusepi & Preston (2008) to explain the transmission of expectations to economic fluctuations, may also explain the findings of this research.

This learning is held to take place among agents who do not receive information directly.

Secondly, results also confirm what some international studies have postulated (among the most recent, Kangasniemiet al., 2010; Kangasniemi & Takala, 2012): that expectation indicators provide valuable information for anticipating and predicting the future of the economy. This work verifies this result for the Uruguayan economy and industrialists' expectations (findings that are in line with previous studies for Uruguay: Lanzilotta, 2006; 2015). Another interesting result of this research is the confirmation that the relationship between expectations and the growth of Uruguayan GDP is non-linear. However, this work did not make any progress in specifying the underlying non-linear model, a topic that may stimulate future research.

The identification of a common trend in industrialists' expectations about the future of the economy, guided by the expectations of the export grouping, reveals and reflects the production structure of what is an open economy whose dynamics are highly dependent on the long-term performance of the external sector.

Although this research is exploratory, its findings have potentially important implications for economic policy. The influence of the most trade-oriented industries on expectations and then on GDP growth is a signal for policymakers seeking to mould expectations and create a climate of optimism during recessions so that their duration is lessened. The question of which factors ultimately determine expectations in these key sectors is certainly one of the issues raised by this study and could be the subject of future research.

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Annex

A1. Unrestricted multivariate structural model

Strong convergence relative to 1e-07 - likelihood cvg 0 - gradient cvg 7.20782e-05 - parameter cvg 0 - number of bad iterations 5 Estimation process completed. UC(111) Estimation done by Maximum Likelihood (exact score) The database used is C:\Users\blanzilotta\Google Drive\iecon\expectativas\2019\estimaciones\series para stamp 2019.xlsx The selection sample is: 1997(4) - 2017(4) (N = 4, T = 81) The dependent vector Y contains variables: xpp bcpp cipp aam The model is: Y = Trend + Irregular + AR(1) + Interventions Component selection: 0=out, 1=in, 2=dependent, 3=fix Level Slope AR(1) Irregular 1 1 1 1 xpp 1 1 1 1 aacd 1 1 1 1 cipp 1 1 1 1 mpp Profile Log-Likelihood: 770.0760 Akaike Information Criterion (AIC): -17.7056 Bayesian Information Criterion (BIC): -16.1388 Prediction error variance/correlation matrix: bcpp xpp cipp gam 0.79833 0.94292 0.02198 0.90177 xpp 0.68227 0.01762 0.01736 0.01805 0.01371 0.01613 0.01384 0.91033 bcpp cipp 0.02325 0.76980 0.01371 0.02325 0.01384 0.01354 mpp 0.01331 Summary statistics: xpp bcpp cipp 70 mpp 73 т
 72
 73
 70
 73

 5.8586
 7.4957
 2.5458
 7.6502

 0.25997
 0.21715
 0.3931
 0.20625

 1.8213
 1.7861
 1.8058
 1.8632

 0.068501
 0.10622
 0.045745
 0.060072
 72 73 Normality H(22) DW r(1) 11 11 4 4 11 11 q 4 р 4 -0.061326 -0.11908 0.039315 -0.066776 r(q) 14.987 9.671 14.384 9.3485 Q(q,q-p) Rd^2 0.27656 0.21453 0.27642 0.34623 Variances of disturbances in Eq xpp: Value (q-ratio) 0.0205955 (61.36) Level 0.000000 (0.0000) 0.00196040 (5.840) 0.000335669 (1.000) Slope AR(1) Irregular Variances of disturbances in Eq bcpp: Value (q-ratio) 0.0157162 (46.82) Level 0.000000 (0.0000) 0.00223273 (6.652) 0.000285120 (0.8494) Slope AR(1) Irregular Variances of disturbances in Eq cipp: Value (q-ratio)

Level	0.0)122566 (36.51)		
Slope	0.	.000000 (0.0000)		
AR(1)	0.00)958622 (28.56)		
Irregu	11ar 0.00)152579 (4.546)		
Varia	nces of distu	rbances in E Value	Eq mpp: (q-ratio)		
Level	0.0)115124 (34.30)		
Slope	0.	.000000 (0.0000)		
AR(1)	0.000)596031 (1.776)		
Irregu	ular 0.000)992445 (2.957)		
Level	disturbance v	variance/com	relation mat	rix:	
	v vsvev		0 00ES		
hcpp	0.02000	0.9724	0.9055	0.9823	
ncpp	0.01/30	0.01012	0.9495	0.9951	
crbb	0.01430	0.01310	0.01220	0.9031	
mpp	0.01513	0.01339	0.01144	0.01151	
Slope	disturbance s	scalar varia	ance matrix:	mon	
vnn	U UUUU 255	0 0000	0 0000	0 0000	
hcpp	0.0000	0.0000	0.0000	0.0000	
ainn	0.0000	0.0000	0.0000	0.0000	
CIPP	0.0000	0.0000	0.0000	0.0000	
шрр	0.0000	0.0000	0.0000	0.0000	
AR(1)	disturbance v	variance/com	relation mat	rix:	
	xpp	bcpp	cipp	mpp	
xpp	0.001960	0.4730	0.9990	0.7573	
bcpp	0.0009897	0.002233	0.4906	0.9311	
cipp	0.004331	0.002270	0.009586	0.7676	
mpp	0.0008186	0.001074	0.001835	0.0005960	
Irregu	ılar disturbar	nce variance	correlation	matrix:	
vnn	0 0003357	0 2503	0 1209	0 9681	
hcpp	7 7420-05	0.2303	-0 9298	0.03544	
cipp	8 6530-05	-0 0006133	0.001526	0 3304	
mpp	0.0005500	1 9950-05	0.001020	0.000024	
шрр	0.0003300	1.0056 05	0.0004000	0.0000024	
AR(1)	other paramet	ters:	bcpp	cipp	നവന
AR coe	efficient	0.61585	0.86513	0.56430	0.12878
State	vector analys	sis at perio	od 2017(4):		
Equat	ion xpp				
	Value	Prob			
Level	-0.13290	[0.00304]			
Slope	-0.00304	[0.85029]			
Equat:	ion bcpp Value	Proh			
T.evel	-0 25807	1100			
Slope	-0 00649	[0.64752]			
stobe	-0.00049	[0.04/52]			
Equat	ion cipp				
	Value	Prob			
Level	-0.14378	[0.05467]			
Slope	-0.00577	[0.64442]			
Equation	aam noi				
	Value	Prob			
Level	-0.38365	[0.000001			
Slope	-0.00723	[0.54920]			

Equation xpp: regression effects in final state at time 2017(4): Coefficient RMSE t-value Prob Outlier 2015(4) 0.13487 0.03550 3.79948 [0.00029] -0.11191 0.03345 -3.34599 [0.00128] Outlier 2016(2) Outlier 1999(4) 0.11321 0.03346 3.38347 [0.00113] Equation bcpp: regression effects in final state at time 2017(4): Coefficient RMSE t-value 0.28518 0.04164 6.84918 Prob Outlier 2004(3) 6.84918 [0.00000] Level break 2005(3) 0.20550 0.05236 3.92449 [0.00019] Level break 2002(4) -0.17811 0.05227 -3.40754 [0.00106] Level break 2016(1) 0.14081 0.05448 2.58481 [0.01169] Equation cipp: regression effects in final state at time 2017(4): Coefficient RMSE t-value Prob 0.33759 0.07522 4.48819 [0.00002] Outlier 1999(2) 0.33759 4.48819 [0.00002] Equation mpp: regression effects in final state at time 2017(4): Coefficient RMSE t-value Prob -0.17752 0.11958 0.03061 Outlier 2002(3) -5.79853 [0.00000] Outlier 2003(4)0.119580.03025Outlier 2005(1)0.109590.03053 3.95296 [0.00017] 3.58973 [0.00059] Level break 2003(2) 0.13565 0.03035 4.46903 [0.00003] Variances of disturbances in Eq xpp: Value (q-ratio) 0.0205955 (0.000000 (Level 0.0205955 61.36) Slope 0.0000) 0.00196040 (5,840) AR(1) 0.000335669 (1.000) Trregular Variances of disturbances in Eq bcpp: Value (q-ratio) (46.82) 0.0157162 Level 0.0000000 (0.00223273 (Slope 0.0000) AR(1) 6.652) 0.000285120 (0.8494) Irregular Variances of disturbances in Eq cipp: Value (q-ratio) 0.0122566 (36.51) 0.000000 (0.0000) 0.00958622 (28.56) Level Slope AR(1) 0.00152579 (4.546) Irregular Variances of disturbances in Eq mpp: Value (q-ratio) 0.0115124 (34.30) Level 0.0000000 (0.000596031 (Slope 0.0000) _____ AR(1) 1.776) 0.000992445 (2.957) Irregular Standard deviations of disturbances in Eq xpp: Value (q-ratio) 0.143511 Level 7.833) (0.000000 (Slope 0.0000) 0.0442764 (2.417) AR(1) 0.0183213 (1.000) Irregular Standard deviations of disturbances in Eq bcpp: Value (q-ratio) 0.125364 (6.843) 0.000000 (0.0000) Level Slope

AR(1)	1	0.0472518	2.579)				
Irregu	ular	0.0168855	0.9216)				
-							
Stands	ard deviati	one of dieti	rhances in F	a cipp:			
Scanac	aru ueviati	Value	(a matic)	d cibb.			
- 1		value	(q-1ac10)				
Level		0.110/10	6.043)				
Slope		0.000000	0.0000)				
AR(1)		0.0979092	5.344)				
Irrequ	ılar	0.0390613	2.132)				
2							
Standa	ard deviati	ons of disti	rhances in F	a mon•			
bcanac	ard deviaer	Value	(a matia)	d mbb.			
		Value	(q=racio)				
Level		0.107296	5.856)				
Slope		0.000000	0.0000)				
AR(1)		0.0244137	1.333)				
Irrequ	ular	0.0315031	1.719)				
2							
Terrel	dieturbanc	a wariance/	orrelation m	atriv.			
пелет	uiscuibanc	e variance/c		atia.			
	xpp	pcbt	o cipp	mpp)		
xpp	0.02060	0.9724	0.9053	0.9823	3		
bcpp	0.01750	0.01572	0.9495	0.9951	-		
cipp	0.01438	0.01318	0.01226	0.9631			
ຫວວ	0.01513	0.01339	0.01144	0.01151			
mp p	0.01010	0.0100.	0.01111	0.01101	-		
01.000	ما با محمد ما م						
stope	disturbanc	e scalar vai	lance matrix	:			
	xpp	pcbt	o cipp	mpp)		
xpp	0.0000	0.0000	0.0000	0.0000)		
bcpp	0.0000	0.0000	0.0000	0.0000)		
qqip	0.0000	0.0000	0.0000	0.0000)		
	0 0000	0 0000	0 0000	0 0000)		
трр	0.0000	0.0000	0.0000	0.0000	, ,		
(4)							
AR(I)	disturbanc	e variance/o	correlation m	atrix:			
	xpp	pcbł	o cipp	mpp)		
хрр	0.001960	0.4730	0.9990	0.7573	3		
bcpp	0.0009897	0.002233	0.4906	0.9311	_		
qqip	0.004331	0.002270	0.009586	0.7676	5		
mpp	0 0008186	0 001074	0 001835	0 0005960)		
трр	0.0000100	0.00107-	0.001033	0.00000000	, ,		
T			/				
Irregu	llar distur	bance variar	ice/correlati	on matrix:			
	xpp	pcbł	o cipp	mpp)		
xpp	0.0003357	0.2503	0.1209	0.9681			
bcpp	7.742e-05	0.0002851	-0.9298	0.03544	Ł		
cipp	8.653e-05	-0.0006133	0.001526	0.3304			
mpp	0.0005588	1.885e-05	0.0004066	0.0009924	L		
mpp	0.00000000	1.00000 00	0.0001000	0.0000002	<u> </u>		
7 7							
Analys	sis of vari	ance matrice	s:				
Level	disturbanc	e variance m	natrix is 4 x	: 4 with impo	osed rank	4 and actu	al rank
Variar		tion matrix					
	nce/correla	CION MACIIX					
	nce/correla xpp	bcpr	o cipp	mpp)		
ααχ	nce/correla xpp 0.02060	bcpr 0.9724	o cipp 0.9053	mpp 0.9823	3		
xpp	nce/correla xpp 0.02060 0.01750	0.9724	cipp 0.9053	mpp 0.9823 0.9951	3		
xpp bcpp	nce/correla xpp 0.02060 0.01750	0.9724 0.01572	cipp 0.9053 0.9495	mpp 0.9823 0.9951	-		
xpp bcpp cipp	nce/correla xpp 0.02060 0.01750 0.01438	0.9724 0.01572 0.01318	cipp 0.9053 0.9495 0.01226	mpp 0.9823 0.9951 0.9631) - -		
xpp bcpp cipp mpp	nce/correla xpp 0.02060 0.01750 0.01438 0.01513	0.01318 0.01572 0.01572 0.01318 0.01339	cipp 0.9053 0.9495 0.01226 0.01144	mpp 0.9823 0.9951 0.9631 0.01151) - -		
xpp bcpp cipp mpp Eigenv	nce/correla xpp 0.02060 0.01750 0.01438 0.01513 vectors and	bcpr 0.9724 0.01572 0.01318 0.01339 eigenvalues	 cipp 0.9053 0.9495 0.01226 0.01144 	mpp 0.9823 0.9951 0.9631 0.01151) - -		
xpp bcpp cipp mpp Eigenv	nce/correla xpp 0.02060 0.01750 0.01438 0.01513 vectors and	bcpr 0.9724 0.01572 0.01318 0.01339 eigenvalues xpp	 cipp 0.9053 0.9495 0.01226 0.01144 bcpp 	mpp 0.9823 0.9951 0.9631 0.01151 cipp	mpp		
xpp bcpp cipp mpp Eigenv xpp	nce/correla xpp 0.02060 0.01750 0.01438 0.01513 vectors and	0.9724 0.01572 0.01572 0.01318 0.01339 eigenvalues xpp -0.5852	 cipp 0.9053 0.9495 0.01226 0.01144 bcpp -0.6194 	mpp 0.9823 0.9951 0.9631 0.01151 cipp -0.4677	mpp 0.2349		
xpp bcpp cipp mpp Eigenv xpp bcpp	nce/correla xpp 0.02060 0.01750 0.01438 0.01513 vectors and	bcpr 0.9724 0.01572 0.01318 0.01339 eigenvalues xpp -0.5852 -0.5160	<pre>> cipp 4 0.9053 2 0.9495 3 0.01226 9 0.01144 5 bcpp -0.6194 0.007489</pre>	mpp 0.9823 0.9951 0.9631 0.01151 cipp -0.4677 0.7954	mpp 0.2349 0.3180		
xpp bcpp cipp mpp Eigenv xpp bcpp cipp	nce/correla xpp 0.02060 0.01750 0.01438 0.01513 vectors and	bcpr 0.9724 0.01572 0.01318 0.01335 eigenvalues xpp -0.5852 -0.5160 (0 -0.4405	<pre>> cipp 0.9053 0.9495 0.01226 0.01144 > bcpp -0.6194 0.007489 0 7845</pre>	mpp 0.9823 0.9951 0.9631 0.01151 cipp -0.4677 0.7954 -0.3794	mpp 0.2349 0.3180 0.2158		
xpp bcpp cipp mpp Eigent xpp bcpp cipp	nce/correla xpp 0.02060 0.01750 0.01438 0.01513 vectors and	0.9724 0.01572 0.01318 0.01339 eigenvalues xpp -0.5852 -0.5160 0.4405	<pre>> cipp 0.9053 0.9495 0.01226 0.01124 > 0.01144 > bcpp -0.6194 0.007489 0.7845 0.0222</pre>	mpp 0.9823 0.9951 0.9631 0.01151 cipp -0.4677 0.7954 -0.3794 0.06542	mpp 0.2349 0.3180 0.2158		
xpp bcpp cipp mpp Eigenv xpp bcpp cipp mpp	nce/correla xpp 0.02060 0.01750 0.01438 0.01513 vectors and	bcpr 0.9724 0.01572 0.01318 0.01339 eigenvalues xpp -0.5852 -0.5160 -0.4405 -0.4442	 cipp 0.9053 0.9495 0.01226 0.01144 bcpp -0.6194 0.007489 0.7845 0.02932 	mpp 0.9823 0.9951 0.9631 0.01151 cipp -0.4677 0.7954 -0.3794 0.06848	mpp 0.2349 0.3180 0.2158 -0.8928		
xpp bcpp cipp mpp Eigenv xpp bcpp cipp mpp eigenv	nce/correla xpp 0.02060 0.01750 0.01438 0.01513 vectors and	bcpr 0.9724 0.01572 0.01318 0.01339 eigenvalues xpp -0.5852 -0.5160 -0.4405 -0.4442 0.05833	<pre>cipp 0.9053 0.9495 0.01226 0.01124 bcpp -0.6194 0.007489 0.7845 0.02932 0.001453 0.</pre>	mpp 0.9823 0.9951 0.9631 0.01151 cipp -0.4677 0.7954 -0.3794 0.06848 0002949 -4.	mpp 0.2349 0.3180 0.2158 -0.8928 802e-19		

Slope disturbance variance matrix is 4 x 4 with imposed rank 4 and actual rank 0 Variance/correlation matrix

xpp	bcpp	cipp		mpp	
0.000.0 qqx	0.0000	0.0000	0.	0000	
bcpp 0.0000	0.000	0.0000	0.	0000	
cipp 0.000	0 0000	0 0000	0	0000	
mp 0.0000	0.0000	0 0000	0	0000	
Eigenvectors and	oigonualuog	0.0000	0.	0000	
Eigenvectors and	ergenvarues	hann	ainn		
	xpp	ddag	1 000	ddiu	
xpp	0.0000	0.0000	1.000	0.0000	
bcpp	0.0000	0.0000	0.0000	1.000	
cipp	1.000	0.0000	0.0000	0.0000	
mpp	0.0000	1.000	0.0000	0.0000	
eigenvalues	0.0000	0.0000	0.0000	0.0000	
percentage	0.0000	0.0000	0.0000	0.0000	
AR(1) disturbanc	e variance m	atrix is 4 x	4 with	imposed rank	4 and actual rank 4
Variance/correla	tion matrix				
xpp	bcpp	cipp		mpp	
хрр 0.001960	0.4730	0.9990	0.	7573	
bcpp 0.0009897	0.002233	0.4906	0.	9311	
cipp 0.004331	0 002270	0 009586	0	7676	
mpp 0.004331	0.002270	0.001835	0 000	5960	
Cholocky docompo	o.ouition IDI	D.0010000	0.000	5500	
choresky decompo	SICION LDL	WICH L AND D			
	a qqx	cpp c	ıpp	mpp	
xpp 1.	0.0	0.00	000	0.0000	
bcpp 0.5	048 1.	000 0.0	000	0.0000	
cipp 2.	209 0.04	816 1.	000	0.0000	
mpp 0.4	176 0.3	813 -0.3	345	1.000	
diag(D) 0.001	960 0.001	733 1.609e	-05 3.	867e-07	
Eigenvectors and	eigenvalues				
	xpp	bcpp	cipp	mpp	
xpp	-0.3913	-0.1377	-0.6191	0.6669	
bapp	-0.2469	0.9024	0.2372	0.2616	
cipp	-0.8677	-0.2606	0.3503	-0.2376	
mon	-0 1819	0 3143	-0 6617	-0 6560	
ajganyaluas	0 01257 0	001801 5	1370-06	1 7180-07	
percentage	87 //	12 53	1378 00 0 03782	0 001195	
percentage	07.44	12.00	0.03702	0.001195	
Irregular distur	bance varian	ce matrix is	4 x 4 w	uth imposed	rank 4 and actual rank 4
Variance/correla	tion matrix				
xpp	bcpp	cipp		mpp	
xpp 0.0003357	0.2503	0.1209	0.	9681	
bcpp 7.742e-05	0.0002851	-0.9298	0.0	3544	
cipp 8.653e-05	-0.0006133	0.001526	0.	3304	
mpp 0.0005588	1.885e-05	0.0004066	0.000	9924	
Cholesky decompo	sition LDL'	with L and D			
	xpp b	срр с:	ipp	mpp	
хрр 1.	000 0.0	000 0.0	000	0.0000	
bcpp 0.2	307 1.	000 0.0	000	0.000	
cipp 0.2	578 -2.	369 1.1	000	0.0000	
C1PP 0.2	665 -0 4	117 0 5	000 070	1 000	
mpp 1.		472 2 2250	06 1	5940 05	
Ulay(D) 0.0003		075 5.2258	-00 1.	3040-03	
Ligenvectors and	ergenvarues	1			
	xpp	qqpa	сірр	mpp	
xpp	-0.1808	0.4807	0.8155	-0.2667	
bcpp	0.2883	0.3224	0.1639	0.8866	
cipp	-0.8303	-0.3772	0.1616	0.3772	
mpp	-0.4414	0.7230	-0.5310	-0.02123	
eigenvalues 0	.001974 0	.001160 4.	581e-06	4.370e-07	
			0 1450	0 01392	

A2. Restricted multivariate structural model

```
Strong convergence relative to 1e-07
- likelihood cvg 0
- gradient cvg 3.4825e-05
- parameter cvg 0
- number of bad iterations 5
Estimation process completed.
UC(110) Estimation done by Maximum Likelihood (exact score)
The database used is C:\Users\blanzilotta\Google
Drive\iecon\expectativas\2019\estimaciones\series para stamp 2019.xlsx
The selection sample is: 1997(4) - 2017(4) (N = 4, T = 81)
The dependent vector Y contains variables:
             bcpp
                          cipp
        xpp
                                            aam
The model is: Y = Trend + Irregular + AR(1) + Interventions
Component selection: 0=out, 1=in, 2=dependent, 3=fix
                 Level
                          Slope AR(1) Irregular
                              1
                                       1
                                              1
                      1
   qqx
                      2
                                 1
                                            1
                                                       1
   bcpp
                                                      1
                                1
                      2
   cipp
                                            1
                      2
                                1
                                            1
                                                      1
   mpp
Profile Log-Likelihood:
                                    770.6330
Akaike Information Criterion (AIC): -17.8675
Bayesian Information Criterion (BIC): -16.4781
Prediction error variance/correlation matrix:
          xpp bcpp
                              cipp
                                             aam
        0.02021
                 0.89729
                             0.79153
                                        0.93804
xpp
       0.01630 0.01633 0.66752 0.89935
bcpp
cipp
        0.01689 0.01281 0.02254
                                      0.76129
        0.01446 0.01246 0.01239
                                         0.01176
mpp
Summary statistics:
                             bcpp
                    хрр
                                         cipp
                                                     mpp
                    72
                            73
                                         70
                                                     73
Т
                3.6559
Normality
                           6.4634
                                      1.5909
                                                  5.4138
               0.24889 0.22633 0.36764 0.21811
Н(22)

        1.7475
        1.6912
        1.8866

        0.10881
        0.14932
        0.016015

                                      1.8866
                                                 1.8323
DW
r(1)
               0.10881
                                               0.077727
                                   11
                          11
                                                11
 q
                 11
р
                     4
                                4
                                                      4
               -0.05246 -0.10037 0.043408 -0.046749
r(q)
 Q(q,q-p)
                15.774
                           6.8589 12.455
                                                 8.7873
 Rd^2
               0.33485
                           0.26135
                                      0.2985
                                                 0.42233
Variances of disturbances in Eq xpp:
                  Value (q-ratio)
             0.00159203 ( 28.23)
Level
              0.000000 ( 0.0000)
Slope
AR(1)
              0.0197893 ( 351.0)
Irregular
           5.63852e-05 ( 1.000)
Variances of disturbances in Eq bcpp:
                  Value (q-ratio)
               0.000000 ( 0.0000)
Slope
AR(1)
              0.0139114 ( 246.7)
Irregular
           0.000325532 ( 5.773)
Variances of disturbances in Eq cipp:
               Value (q-ratio)
0.000000 ( 0.0000)
Slope
              0.0142313 ( 252.4)
AR(1)
           0.00262083 ( 46.48)
Irregular
```

Variances of disturbances in Eq mpp: Value (q-ratio) 0.000000 (0.0000) Slope AR(1) 0.00910548 (161.5) Irregular 0.000624735 (11.08) Level disturbance variance/correlation matrix: xpp bcpp cipp 0.001592 1.000 1.000 mpp 1.000 хрр 1.000 1.000 1.000 bcpp 0.002203 0.003048 cipp 0.002969 0.004108 0.005538 0.001934 0.002676 0.003607 0.002350 mpp Level disturbance factor variance for xpp: 0.00159203 Level disturbance factor loading matrix: хрр 1.384 gaod cipp 1.865 mpp 1.215 bcpp cipp mpp 0.03994 0.2439 -0.1556 xpp 0.0000 Constant Slope disturbance scalar variance matrix: xpp bcpp cipp 0.0000 0.0000 0.0000 0.0000 mpp 0.0000 0.0000 0.0000 хрр
 0.0000
 0.0000

 0.0000
 0.0000

 0.0000
 0.0000

 0.0000
 0.0000
 0.0000 bcpp cipp 0.0000 mpp 0.0000 0.0000 AR(1) disturbance variance/correlation matrix: xpp bcpp cipp mpp 0.8796 0.9762 0.01979 0.9114 хрр 0.01512 0.01391 0.7597 0.01476 0.01069 0.01423 0.9406 0.7650 bcpp 0.01476 0.01069 0.01310 0.01059 cipp 0.008709 0.009105 mpp Irregular disturbance variance/correlation matrix: xpp bcpp cipp mpp 0.1148 -0.9761 5.639e-05 0.08938 0.9238 xpp
 hpp
 1.211e-05
 0.0003255
 -0.9761
 -0.1226

 cipp
 4.414e-05
 -0.0009016
 0.002621
 0.3351

 mpp
 0.0001734
 -5.531e-05
 0.0004288
 0.0006247
 -0.1226 AR(1) other parameters: bcpp cipp xpp mpp 0.80226 0.85589 0.75111 0.78937 AR coefficient State vector analysis at period 2017(4): Equation xpp Value Prob -0.26504 [0.06225] Level -0.00379 [0.47879] Slope Equation bcpp Value Prob -0.32680 [0.07558] Level -0.00702 [0.32178] Slope Equation cipp Value Prob Level -0.25042 [0.02340]

Slope -0.00651 [0.45208]

Equation mpp Value Prob -0.47756 [0.00001] Level Slope -0.00789 [0.17560] Equation xpp: regression effects in final state at time 2017(4): Coefficient RMSE t-value Prob Outlier 2015(4) 0.12698 0.03494 3.63437 [0.00050] -0.11686 0.03361 Outlier 2016(2) -3.47664 [0.00084] 0.10348 0.03355 3.08382 [0.00285] Outlier 1999(4) Equation bcpp: regression effects in final state at time 2017(4): Coefficient RMSE t-value Prob
 Outlier 2004(3)
 0.29154
 0.04214

 Level break 2005(3)
 0.20038
 0.05122

 Level break 2002(4)
 -0.18140
 0.05143
 6.91790 [0.00000] 3.91189 [0.00020] -3.52684 [0.00072] Level break 2016(1) 0.16518 0.05231 3.15782 [0.00229] Equation cipp: regression effects in final state at time 2017(4): Coefficient RMSE t-value Prob Outlier 1999(2) 0.32352 0.07602 4.25578 [0.00006] Equation mpp: regression effects in final state at time 2017(4): Coefficient RMSE t-value Prob -0.17993 0.03099 Outlier 2002(3) -5.80682 [0.00000] Outlier 2003(4)0.124360.030564.06890[0.00012]Outlier 2005(1)0.114160.030683.72066[0.00038] Outlier 2005(1)0.114160.030683.72066[0.00038]Level break 2003(2)0.140050.031914.38930[0.00004]

A3. Rank test for cointegration and Rank test for (neglected) nonlinearity

Rank test for cointegration

Breitung (2001) introduces a nonparametric test procedure to test the hypothesis of a cointegration relationship and to identify whether this link is nonlinear. Breitung procedure proposed a rank transformation for the series involved and 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.

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

$$\mu_t = g(y_t) - f(x_t) \tag{1}$$

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

$$\mathbf{R}_{\mathrm{T}}\left[f(x_{\mathrm{t}})\right] = \mathbf{R}_{\mathrm{T}}(x_{\mathrm{t}}) \tag{2}$$

and

$$\mathbf{R}_{\mathrm{T}}[g(\mathbf{y}_{\mathrm{t}})] = \mathbf{R}_{\mathrm{T}}(\mathbf{y}_{\mathrm{t}}) \tag{3}$$

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^* :

$$K_{\rm T}^* = {\rm T}^{-1} \max_{\rm t} |{\rm d}_{\rm t}| / \hat{\sigma}_{\Delta \rm d} \tag{4}$$

$$\xi_{\rm T}^* = {\rm T}^{-3} \sum_{\rm t=1}^{\rm T} {\rm d}_{\rm t}^2 / \hat{\sigma}_{\Delta \rm d}^2, \tag{5}$$

where

$$d_t = R_T(y_t) - R_T(x_t), \tag{6}$$

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

$$\hat{\sigma}_{\Delta d}^2 = T^{-2} \sum_{t=2}^{T} (d_t - d_{t-1})^2$$
(7)

adjusts for possible correlation between the series of interest.

Rank test for (neglected) nonlinearity

If cointegration is not neglected in the first step, then we test the linearity of the cointegration relationship. For a convenient representation of the alternative and null hypothesis Breitung (2002) follows Granger (1995) and represents the nonlinear relationship as:

$$y_t = \gamma_0 + \gamma_1 x_t + f^*(x_t) + u_t,$$
(8)

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 instead of using $f^*(x_t)$.

Under the assumption 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*R² statistic of the MCO:

$$\tilde{u}_t = c_0 + c_1 x_t + c_2 R_t(x_t) + e_t.$$
(9)

Breitung (2001) generalizes the score test for the ECM representation and applies 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:

$$y_{t} = \alpha_{0} + \sum_{i=1}^{p} \alpha_{1i} y_{t-i} + \alpha_{2} x_{t} + \sum_{i=-p}^{p} \alpha_{3i} \Delta x_{t-i} + u_{t}$$
(10)

$$\tilde{u}_{t} = \beta_{0} + \sum_{i=1}^{p} \beta_{1i} y_{t-i} + \beta_{2} x_{t} + \sum_{i=-p}^{p} \beta_{3i} \Delta x_{t-i} + \dots + \theta_{1} R_{T}(x_{t}) + \dots + \tilde{v}_{t},$$
(11)

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 $R_T(x_{it})$.

Under the null hypothesis, it is assumed that the coefficients for the ranked series are equal to $\text{zero}, \theta_1 = 0$. 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 favour of nonlinear relationship if the score statistic value exceeds the χ^2 critical values with one degree of freedom (when two variables are involved).

Causality Rank Test

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. For these cases, Holmes & Hutton (1990) proposed a multiple rank F-test, more robust than the standard Granger causality test. In case that the conditions of Granger estimations are satisfied, the multiple rank F-test results are alike the Granger results.

Holmes & Hutton (1990) analysed 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 valid for both weak and strong relationships between the variables.

The Holmes & 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 as:

$$R(y_t) = a_0 + \sum_{i=1}^p a_{1i} R(y_{t-i}) + \sum_{i=1}^q a_{2i} R(x_{t-i}) + e_t$$
(14)

$$R(x_t) = b_0 + \sum_{i=1}^p b_{1i} R(x_{t-i}) + \sum_{i=1}^q b_{2i} R(y_{t-i}) + \varepsilon_t, (15)$$

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, and 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 (14) rejection of the null hypothesis $(a_{2i} = 0)$ implies causality from X to Y; whereas in (15), 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.