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By: Luz A. Flórez, Karen L. Pulido-Mahecha, Mario A. Ramos-Veloza

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OKUN´S LAW IN COLOMBIA: A NON-LINEAR COINTEGRATION APPROACH

Luz A. Flórez
Banco de la República - Medellín

Karen L. Pulido-Mahecha
Universidad Nacional

Mario A. Ramos-Veloza[*]
Banco de la República-Bogota

Abstract

This paper identifies Okun´s law in Colombia between 1984 and 2016 using a Vector Error Correction Model (VECM) as there is evidence of a long-term relationship between the unemployment rate and the GDP. Results suggest that after a one percent increase in GDP, the unemployment rate is reduced by 0.45 percentage points in the long run (after sixteen quarters). In addition we inspect for nonlinearities using a threshold cointegration model (TVECM). Results suggest the existence of two regimes a low and a high one. The high regime starts at the late nineties and is associated with a more flexible labor market. Under this regime, a 1% increase in GDP, reduces the UR 0.6 percentage points after eighteen quarters. By contrast, under the low regime the response is 0.2 percentage points after eight quarters.

JEL classification: E24, J3, J4
Keywords: Okun´s law, co-integration, nonlinearities.

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1. INTRODUCTION

Okun´s law is an empirical regularity that shows the association between unemployment rate and economic growth. It is named after Arthur Okun (1962) who suggested that a one-percentage point increase in the unemployment rate is associated with a three-percentage points (pp) fall in the US output. Further research showed that Okun's Law also held in other industrialized countries but with a different magnitude to that estimated for the US. For instance, in France and Germany the impact was lower given the lower flexibility of their labor markets. Understanding Okun's Law does not require a great deal of economic knowledge, which makes it attractive and very useful for non-specialized audiences, it also has proved to be a power and useful for forecasting [Mitchell and Pearce (2010)].

Originally Okun proposed two specifications: *the difference and the GAP specifications*. While in the *difference specification* the contemporaneous correlation between the change in unemployment and economic growth is inspected, in the *gap specification* the cyclical relationship is inspected. The cyclical component is computed by removing the permanent component from the series. Thus, both the differentiation and the subtraction of the long-run trend eliminate any low frequency movements. The OLS estimates (called the Okun's Law coefficient (OLC)) capture the short-run relationship. No specification is inherently superior/preferable given that both have their drawbacks. While the difference specification does not capture structural changes the gap specification requires the knowledge of the potential GDP and the natural unemployment rate, which are unobservable variables [Knotek (2007)].

Vector Autoregressive models (VAR) have also been used to study Okun´s relationship given that past levels of output may affect current unemployment dynamics, allowing for flexibility in the timing of the response then the whole effect is not forced to take place immediately. However, this poses a problem as the interpretation is not straightforward as in the static specification.[1] Following this dynamic analysis, researchers have included the possibility of cointegration among the variables; that is the existence of a stable long-run relationship between output and unemployment. Under these conditions a VEC model would better predict the response of output to a drop in employment than a VAR model [Attfield & Silverstone (1997), Lee(2000)]. Lee (2000) provides evidence that Okun´s law holds between 1995 and 1996 in 16 OECD countries with remarkable differences in the estimates across countries. His analysis also considers that the short-run response can be affected by the long term relationship of these variables and the existence of asymmetries.

[1] Another approach to estimate Okun´s Law is to provide an underlying production function that describes the relationship between output and employment. Using a particular production function, it is possible to account for all components that determine total output. Thus, output is derived from employment, capital and technology and the evolution of the output is determined by job creation and total factor productivity (TFP) (e.g. Luchetta and Paradiso (2014)).

He also shows that the "*Gap specification"* estimates are very sensitive to the detrending methodology selected.

A more recent question is whether the response is stable over time as economic conditions, institutions, and the business cycles change. As social institutions, regulations and productivity vary among countries, the mechanisms through which the Okun's Law operates in each country may differ. Hence, researchers have extended its focus to examine other labor market indicators and whether there is a symmetric response across the business cycle. For example, Ball, et al (2013, 2016) found evidence in favor of Okun´s Law in developed and in developing countries, with a lower response to economic fluctuations in developing countries. Moreover, in developing countries they found huge heterogeneity of the OLC and in the adjustment measure of the model (R^2). Additionally, they inspected institutional and economic factors that may account for that heterogeneity and found that the mean unemployment and the share of the services in the GDP were the key variables to explain that difference among countries. The asymmetric responses of the unemployment rate to the cycle has also been introduced in theoretical model. Gomme (1999) introduced a shirking option into a real business cycle model and found a higher unemployment response after a negative shock as compared to a positive shock. Schettkat (1996) used flows from unemployment to employment to find that the introduction of hiring costs caused an asymmetric response of the unemployment rate over the business cycle.

Empirical evidence of nonlinearities is presented by Bodman (1988), Meyer and Tasci (2012), Owyang and Sekhposyan (2012), and Daly, et al., (2014) who found a higher response of unemployment during recessions as compared to expansions. On the other hand, Virén (2001) found a stronger effect when the economy was in a boom for most of twenty OECD countries. Altissimo and Violante (2001) showed that the propagation of output shocks took longer during recessions than expansions. The introduction of nonlinearities has also been used in the cointegration framework. For example, Shin et al (2014), proposed the NARDL in which the short and long run dynamics could be asymmetric. Chinn et al (2013), presented a smooth transition VECM with a unique long run relationship but the short run dynamics and the speed of adjustment varied over expansions and recessions. The threshold cointegration model (TVECM) that is similar to the smooth transition VECM, has been introduced by Balke and Fomby (1997).

In Colombia González (2002), DANE (2006), Guillén (2010), Páez (2013), Cuervo y Mondragón (2016) estimated Okun´s Law using static specifications. These authors estimated an OLC in the range of -0.43 to -0.52 for Colombia, except for DANE whose estimate was lower at -0.17. All these studies, however, have two limitations: they have not explored neither the possibility of a dynamic relationship nor the existence of cointegration or asymmetries over the business cycle. Hence, the main objective of this paper is to explore the best specification of the empirical relationship between the unemployment rate and the GDP for Colombia during the period 1984 and 2016, allowing for cointegration and asymmetries in the response across the business cycle.

Our paper contributes to the applied literature in Colombia allowing for a dynamic response in a VECM framework[2]. Our results indicate that after a 1% increase in the quarterly growth of GDP the unemployment rate is reduced by 0.45 pp in the long run. We also find evidence of a non-linear relationship between unemployment rate and GDP. This is why we estimate a TVECM model with two regimes; one that we call a *low* regime characterized with low labour market flexibility and another that we call *high* associated with a higher flexibility of the labor market due to changes in regulation and economic conditions. We find that in the latter regime a 1% increase of the GDP reduces the unemployment rate by 0.6 pp after eighteen quarters, while under the low regime this response is about 0.2 pp after eigh quarters. This paper is divided in four sections being first this introduction. The second section describes the static and dynamic specifications that have been used in the economics literature to estimate Okun's law. The third section briefly discusses the data and presents the estimates from the static and dynamic versions previously presented, focusing on the threshold cointegration model (TVECM). Finally, in the last section we summarize the results.

2. EMPIRICAL SPECIFICATIONS

2.1 THE TRADITIONAL STATIC SPECIFICATIONS OF OKUN´S LAW

Okun (1962) suggested two linear specifications to characterize the relationship between the unemployment rate and the output: *i)* in first difference *ii)* in gaps. The first differences model captures how changes in the unemployment rate from one quarter to the next are related to economic growth:

$$\Delta u_t = \beta_0 + \beta_1 \, \Delta y_t + \varepsilon_t \qquad (1)$$

Where Δu_t represents the first difference of the unemployment rate (quarterly change) and Δy_t the first difference of the logarithm of output (quarterly growth). The parameter β_1 is the Okun coefficient and is expected to be negative, as the simultaneous correlation is negative. The ratio $\frac{\beta_0}{-\beta_1}$ represents the growth rate that is consistent with a constant unemployment, where higher levels of economic growth with respect to that benchmark lead to reductions in the unemployment rate.

The gap model relies on the cyclical component of the series or difference between actual and potential output, and the difference between the current unemployment rate and the one that do not generates inflationary pressures (known as Non-Acelerating Inflation Rate of Unemployment – NAIRU- which by definition is consistent with potential output). Thus, a high unemployment rate is associated with idle resources.

[2] In these paper we also explore the NARDL methodology but we do not find evidence of an asymmetric respond during recessions and expansions. Results are available upon request.

$$u_t - u_t^* = \beta_1(y_t - y_t^*) + \varepsilon_t \quad (2)$$

Where u_t^* represents the natural rate of unemployment or NAIRU such that $u_t^c \equiv u_t - u_t^*$ is the cyclical unemployment rate (unemployment gap). Correspondingly, y_t^* represents the potential level of output under full employment, y_t is the GDP at time *t*, thus the cyclical level of output or output gap is $y_t^c \equiv y_t - y_t^*$. The main drawback of equation (2) is that potential output and natural rate of unemployment or NAIRU are unknown, when their estimates come from approximations made using econometric techniques. While Okun (1962) used exponential or logarithmic linear trend to capture the permanent component, nowadays more advanced techniques have been developed to decompose a series Hodrick–Prescott (1997), Christiano-Fitzgerald (2003), and Baxter-King (1999). Some of these methodologies are used in the next section.

2.2 DYNAMIC SPECIFICATIONS

Okun (1962) also suggested that current and past levels of output may affect unemployment, then equation (1) would be miss-specified and lags of the change in both variables must be included. Thus the unemployment rate is not restricted to a simultaneous response, which implies that the whole effect may take several periods. Under this specification is possible to determine how long it will take for the propagation of a shock in economic growth. The equation for the change in the unemployment rate from a Vector Autoregressive models, or VAR (*p*) model will be:

$$\Delta u_t = \beta_0 + \sum_{i=1}^{p} \beta_i \Delta y_{t-i} + \sum_{i=1}^{p} \phi_i \Delta u_{t-i} + \varepsilon_t \quad (3)$$

Where the parameters $\beta_i, i = 1, \dots, p$ capture the effect on Δu_t of short-run GDP growth and $\phi_i, i = 1, \dots, p$ capture the effects of short-run unemployment changes. However, as pointed out by Attfield and Silverstone (1997) if the GDP and the unemployment rate are cointegrated, the VAR model is misspecified. Then, the correct specification in this case is a Vector Error Correction Model (VECM), which takes into account the long-run relation.

$$\Delta u_t = \alpha(y_{t-1} + \delta u_{t-1} + c) + \sum_{i=1}^{p} \beta_i \Delta y_{t-i} + \sum_{i=1}^{p} \phi_i \Delta u_{t-i} + \varepsilon_t \quad (4)$$

In equation (4) the short-run dynamics of the unemployment rate (Δu_t) does not only depend on the VAR(p) specification but also on the previous period misalignment ($y_{t-1} + \delta u_{t-1} + c$) from the long run equilibrium. The parameter α represents the speed of adjustment of the unemployment rate to the long run equilibrium [Hamilton (1994), chapter 19, p. 581]. With δ and c are the parameters of the long-term relationship between GDP and the UR.

A more general specification involves the existence of different regimes in the economy which implies an asymmetric relation. Given that social institutions, regulations and productivity might change over time, the relation between the unemployment rate and GDP might change. Then we inspect one nonlinear model, the threshold cointegration model (TVECM), introduced by Balke and Fomby (1997). This technique assumes a linear long-term relationship with short-run parameters and speed of adjustment that depend on the regime. Moreover, the speed of adjustment will change with the regime. The VECM model is a special case of the TVECM with only one regime. The specification of TVECM model would depend on the number of regimes taking into account. Following, Hansen and Tseo (2002), a two regimes model for Δu_t is given by:

$$\Delta u_t = \begin{cases} \alpha^L(w_{t-1}) + \sum_{i=1}^{p} \beta_i^L \Delta y_{t-i} + \sum_{i=1}^{p} \phi_i^L \Delta u_{t-i} + \varepsilon_t & if\ w_{t-1} \leq \gamma \\ \alpha^H(\mathrm{w_{t-1}}) + \sum_{i=1}^{p} \beta_i^H \Delta y_{t-i} + \sum_{i=1}^{p} \phi_i^H \Delta u_{t-i} + \varepsilon_t & if\ w_{t-1} > \gamma \end{cases} \quad (5),$$

Where $w_{t-1} = \mathrm{y_{t-1}} + \delta \mathrm{u_{t-1}} + \mathrm{c}$, represents the previous lag of the error-correction term, and is used to define γ, the threshold parameter for the change on the regimen.

3. Okun´s Law Estimates

3.1 Data

We use quarterly data of the unemployment rate and the Gross Domestic Product (GDP) since 1984 to estimate the Okun´s law relationship. The GDP corresponds to the value of the good and services produced in Colombia according to the National Department Administrative of Statistics (DANE). During the period of analysis four methodologies were used. The first methodology provides data for the evolution of domestic production in Colombia between 1984 and 1989, using a laspeyres index with 1975 as the reference year, for the basket of goods and services. The second methodology updates the reference year and the basket used to measure the evolution of production to 1994, and the third methodology updates the reference year to 2000. The most recent methodology starts in 2005 when DANE changed the reference year and the aggregation to a chain index. We generate our historic quarterly series using the percentage change between periods before 2005 according to the prevailing methodology.

The unemployment rate is also computed by the DANE since 1984, using surveys to households in the main cities of Colombia. These surveys provide the longest time series and are the most important source of labor market information covering job, earnings and basic education. Between 1984 and 2000, Household Survey was called *Encuesta Nacional de Hogares*, it was quarterly and covered the seven main cities (Bogotá, Cali, Medellin, Barranquilla, Bucaramanga, Manizales and Pasto). Starting from 2001 the methodology changed to adapt to the International Labour

Organization (ILO) international standards and the survey changed its name to *Encuesta Continua de Hogares*. DANE began to gather data on a monthly basis; also the geographic coverage was increased to the thirteen main cities. Moreover, there were changes in the definitions and criteria of the main indicators (including the unemployment rate). In July 2006, the implementation of methodology changed, introducing a personal interview survey that include different technological changes. Since then the household survey has been called *Gran Encuesta Integrada de Hogares*.

We select the unemployment rate of the seven main cities because it is the longest and more homogenous available series. While the change between 2000 and 2001 has important differences, according to Arango et al. (2008), the change in 2006 does not affect the definitions nor the main indicators of the surveys. To correct for these methodological changes we follow Arango et al. (2008) who adjust the main labor market series to accommodate changes in the survey carried out in 2000. The seasonal component of the GDP and the unemployment rate was removed using X12 and the remaining series are integrated of order 1 as we present them in Appendix I.

3.2 STATIC RESPONSE

Table 1 presents the OLC estimates under five static specifications for the difference and gap models (equations 1 and 2). The first panel corresponded to the quarterly and the annual change of the variables, while the second panel corresponded to the estimates of the gap models using three filters to decompose each time series among its cyclical and permanent component: Hodrick–Prescott (1997), Christiano-Fitzgerald (2003) and Baxter-King (1999).

Thus, a 1% increment in the quarterly growth of the GDP reduces the unemployment rate by 0.12 pp, while a 1% increase in the annual growth reduces the unemployment rate by 0.40 pp. Hence, the response with quarterly data is about one fourth of the one using annual changes; this fact is consistent with findings by Knotek (2007). Also, estimates are similar to previous findings for Colombia using quarterly data (see DANE (2006)). The OLC using annually change or filters ranges from -0.35 pp to -0.44 pp similar to previous findings that use annual data in their estimations (see González (2002), DANE (2006), Guillén (2010), Páez (2013), Cuervo y Mondragón (2016)).

TABLE 1: COMPARISON OF OKUN'S LAW COEFFICIENT

Methodology	OLS
Difference model	
Quarterly change	-0.119**
	(0.05)
Annual change	-0.398***
	(0.03)
Gap model	
Hodrick-Prescott	-0.363***
	(0.04)
Christiano-Fitzgerald	-0.355***
	(0.02)
Baxter-King	-0.431***
	(0.04)

Standard deviation in parentheses

** p<0.10, ** p<0.05, *** p<0.01

Note: Table 1 presents the OLS Okun's law coefficients for Colombia with data between 1984 and 2016 using differences and gap model. The first two rows correspond to the quarterly and annual change, the last three rows correspond to estimates using the gap model the Okun's law with the Hodrick-Prescott, Christiano-Fitzgerald and Baxter-King filters.

3.3 DYNAMIC RESPONSE

The unemployment rate may not only respond to current but also to lagged changes in output. To allow for response in more than one period over time and capture the dynamic behavior of both series we inspect a VAR and VEC models. As presented in Appendix II the unemployment rate and the GDP are integrated of order one (I(1)), then we check for cointegration by using the Engle and Granger (1987) and Phillips and Ouliarius (1990) cointegration tests. Results show that the series are in fact cointegrated and its relationship can be approximated using a Vector Error Correction Model-VECM. We select five lags in equation (4) in order to satisfy normality, no serial correlation, and the AIC criteria.

Under this methodology, the interpretation of the GDP impact on the unemployment rate is not as straightforward as in the static case. First, the unemployment rate may react during several quarters after a GDP innovation and second the adjustment to the long run relationship also contributes to the short-run dynamics. Figure 1 shows the cumulative response of the 1% innovation of the GDP on the unemployment rate. After sixteen quarters the unemployment rate slowly declines and stabilizes around -0.45 pp, which implies a higher response than the static estimate (see Table 2).

TABLE 2: ESTIMATES OF A VEC MODEL WITH FIVE LAGS.

Quarterly data

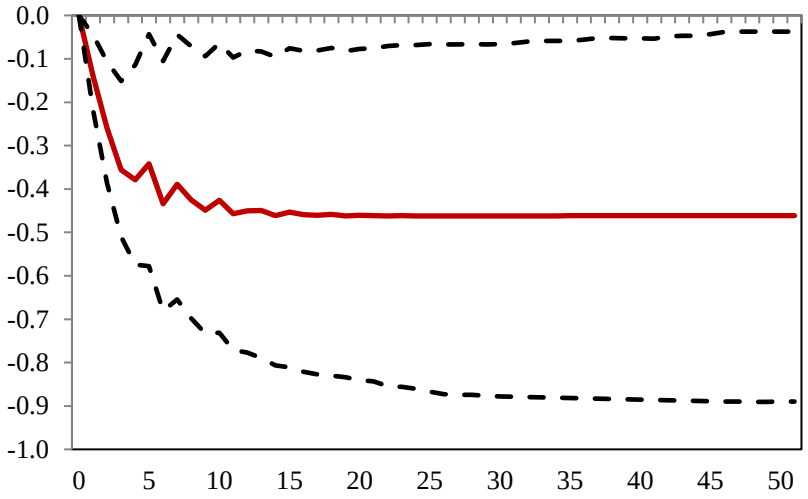
Cointegrating Equation		
GDP_{t-1}	1.00	
UR_{t-1}	35.60	
Constant	-24.31	
Error Correction Model		
	GDP equ	*UR equ*
α	-0.0016***	-0.00015
	(0.0003)	(0.0159)
ΔUR_{t-1}	-0.599***	-0.020
	(0.17)	(0.09)
ΔUR_{t-2}	-0.530***	-0.033
	(0.18)	(0.10)
ΔUR_{t-3}	-0.471**	0.178*
	(0.18)	(0.10)
ΔUR_{t-4}	-0.154	-0.122
	(0.18)	(0.10)
ΔUR_{t-5}	-0.179	0.085
	(0.18)	(0.10)
ΔGDP_{t-1}	-0.348***	-0.125**
	(0.09)	(0.05)
ΔGDP_{t-2}	0.128	-0.138**
	(0.10)	(0.06)
ΔGDP_{t-3}	-0.102	0.005
	(0.10)	(0.06)
ΔGDP_{t-4}	-0.292***	0.080
	(0.10)	(0.05)
ΔGDP_{t-5}	-0.053	-0.074
	(0.09)	(0.05)

Standard deviation in brackets

** p<0.10, ** p<0.05, *** p<0.01

Note: Table 2 presents Okun's law coefficients for Colombia using a VECM (5). The estimation uses a sample from 1984q1 to 2016q4 and includes an intercept (no trend) in cointegration relation - no intercept in VAR. One cointegration relationship is estimated.

FIGURE 1: IMPULSE RESPONSE OF THE UR TO A 1% INCREASE IN GDP
1984q1-2016q4



Source: Authors' calculation.

Note: Figure 1 presents the response of the unemployment rate to 1% growth of the quarterly GDP. We used a VEC with five lags.

The VEC model works better than the static specifications one given the existence of cointegration (Attfield and Silverstone 1997), however it assumes a symmetric response of the unemployment rate to GDP innovations[3]. A model that allows for changes in the relationship along the period would be more appropriate. For example, during the last two decades several aspects of the labor market have changed in Colombia: regulation, structure, and economic conditions. First, changes in regulation that modify the direct costs of hiring and firing workers, may have affected the channels of interaction between unemployment and economic growth.[4] Second, labor market structure has changed as the matching between firms and workers is less costly. Indirect costs of search have been reduced due to the introduction of technology information systems, private employment agencies, and the introduction of the *Servicio Público de Empleo*.[5] (Arango and Flórez (2016)). Third, incentives to the creation of small and medium size firms allowed an important proliferation of these firms, becoming nowadays the main source of employment growth (Flórez et al (2017)).[6] The important growth of these small and medium firms may affect Okun´s Law as they respond in a different way to economic conditions and institutions. Fourth, the diminishing

[3] We also estimate a Structural VEC which allow us to identify the supply shocks using Blanchard and Quah (1989) restrictions. The results are similar to those found with the VECM

[4] For instance, the 789 Law of 2002 reduced firms` firing costs and payment for extra hours. Moreover, non-wage costs have been reduced in the laws 797 (2003), 1429 (2010) and 1607 (2012).

[5] *Servicio público de Empleo* is a public employment agency adscript to the Ministry of Labor which main objective is to improve the matching between firms and workers.

[6] Law 1429 of 2010 of "Formalization and Job creation" brings benefits on tax reductions, access to government support programs and simplified administrative and legal procedures to newly created firms.

importance of the minimum wage as determinant of both the natural unemployment rate and the unemployment rate (see Arango, et al. (2016, 2017))[7]. Thus, it is rational to expect that changes on the transmission channel of the minimum wage to the economy also change the relationship between the unemployment rate and the GDP. Finally, after the economic crisis of the late nineties, and the openness to international trade, there was an increase in the introduction of temporary contracts that allows firms to respond in a more flexible way to an economic crisis and to be able to compete internationally (Heckman and Pagés (2004)). All these changes in the labor market across the last two decades might have changed the relation between UR and GDP across time.

Given these considerations we check for nonlinearities in each series and in the cointegration context. First, we inspect evidence of unit root in a non-linear framework for the UR and GDP. First, we used Andrews and Zivot (1992), Perron and Vogelsang (1992) and Clemente et al., (1988) tests to identify possible breakpoints in each variable. Table 3 presents the results for the Clemao-Montanés-Reyes Test (CMR) that identifies the existence of unit root in a series with up to two breakpoints due to innovational or additive outliers, as we argue structural changes are related with economic slowdowns, changes in regulation or in the methodology of household surveys.

TABLE 3: CLEMAO-MONTAÑÉS-REYES UNIT ROOT TEST

Variable	Specification	5% Critical Value	Dummy δ 1	Dummy δ2	$\rho - 1$	Breakpoint
			Levels*			
UR	AO	-5.49	21.88	-16.52	-4.00	1998q1 , 2004q4
	IO	-5.49	4.60	-4.45	-4.81	1997q3 , 2003q2
GDP	AO	-5.49	15.12	19.29	-3.03	1991q3 , 2008q1
	IO	-5.49	3.69	1.59	-3.48	2002q4 , 2010q2
			Differences*			
UR	AO	-5.49	4.50	-4.97	-13.41	1995q1 , 2000q3
	IO	-5.49	4.70	-5.35	-13.31	1994q4 , 2000q4
GDP	AO	-5.49	-4.69	4.65	-16.77	1997q4 , 1999q2
	IO	-5.49	-6.61	6.55	-17.30	1998q1 , 1999q1

Note: Table 3 presents the Clemao - Montañés-Reyes Unit Root tests for the Gross domestic product (PIB) and the seasonally adjusted unemployment rate. The first four rows show the test for the levels of the series and the last four for the first differences. The first panel of the table presents the results for the series in levels while the second reports the first difference of the series. The first column describes the specification used, whether an additive outlier (AO) or an innovational outlier (IO) were included in a standard Dickey Fuller test. The third column presents the critical value at the 5% of significance, the third and fourth columns presents the t-statistics of the breakpoints analyzed. The fifth column reports the t-statistic under the null hypothesis of unit root, finally the last columns present the breakpoint dates. We used five lags for the test.

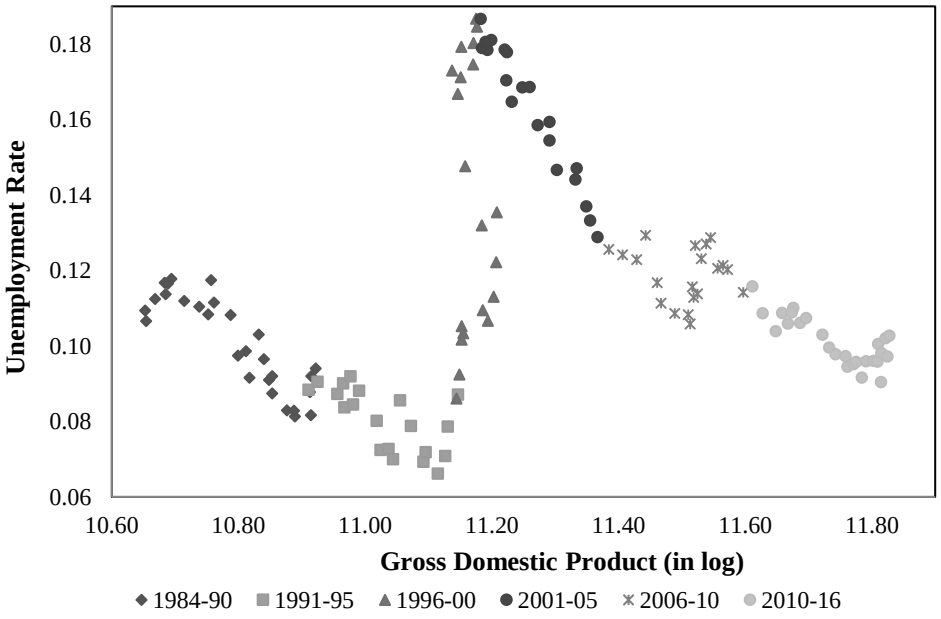
[7] Arango et al (2017) show that an increase in the minimum wage has a positive effect on informality, but not a significant effect on unemployment.

The first panel of the table presents the results for the levels of the series while the second reports the results for the first differences. The first column describes the specification used, whether an additive outlier (AO) or an innovational outlier (IO) were included in a standard Dickey Fuller test. The second column presents the critical value at the 5% of significance, the third and fourth columns present the t-statistics of the first and second breakpoints analyzed. The fifth column reports the t-statistic for $(\rho - 1)$ under the null hypothesis. Finally, the last column presents the breakpoint dates. Results show the existence of structural changes and unit root in the series in level. First, the t-statistic of IO and AO are significant at the 5% critical value, then we cannot reject null hypothesis of unit root for the series in levels. Second, the first differences of both series show evidence of stationarity with structural changes. These results are similar to those of the Andrews and Zivot and Perron and Vogelsang tests (see Appendix III). The breakpoints coincide with the crises in the late nineties which had a strong effect over the Colombian economy, and the methodological changes in the household surveys.

Additionally, the structural breakpoints identified by the CMR test are also identified when we analyze the relationship between the GDP in logs and the UR over time. Figure 2 presents the dynamics of these two variables. As we expect there is a clear negative relationship between UR and GDP as the Okun Law suggest, however, there is a structural breakpoint during the period 1996-2000, as is suggested by the CMR test.

FIGURE 2: RELATIONSHIP BETWEEN THE UR AND GDP ACROSS TIME

1984q1-2016q4



Source: Authors' calculation.

Note: Figure 2 presents the scatter plot between the unemployment rate and the GDP between 1984 and 2017.

The existence of nonlinearities in the original series may imply that also the long-run relationship is non-linear. Thus, to check for non-linear cointegration we perform the Hansen and Seo (2002) test, which contrasts the null hypothesis of linear cointegration (VECM) versus threshold cointegration (TVECM). Results in Table 4 are evidence in favor of a threshold cointegration model.

TABLE 4: THRESHOLD COINTEGRATION TEST

Hansen and Seo (2002)

Deterministic	5% Critical Value	Test Statistic
Constant	11.66	12.21

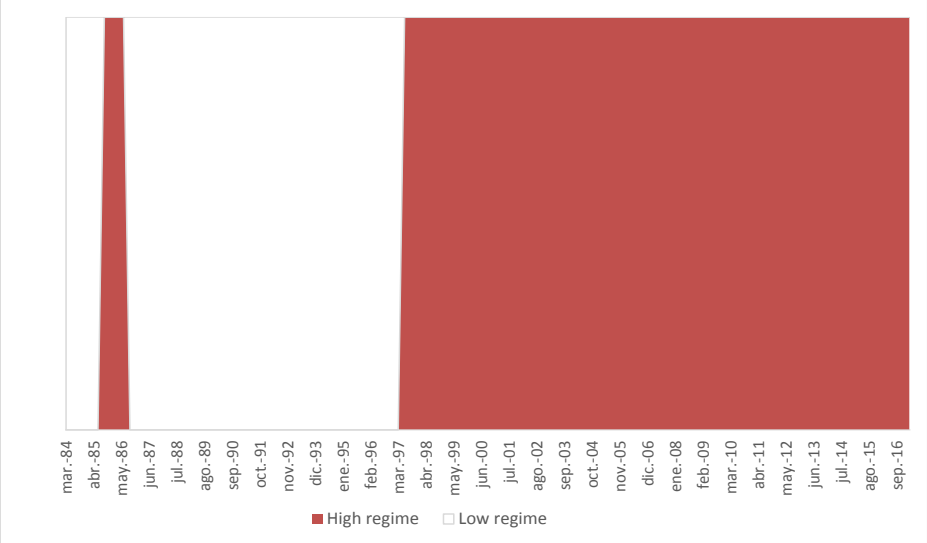
Table 4 presents the Hansen and Seo test for cointegration between the UR and GDP. The first column presents the critical value while the last column reports the t-statistic.

According to those results, we estimate a threshold cointegration VECM with two regimes as in Balke and Fomby (1997).[8] The variable that determines the threshold and therefore the regime is the moving average of order four of the vector error term,[9] using the estimates from the lineal VECM. Thus, we replace w_{t-1} in equation (5) with $\widetilde{w}_t = \frac{w_{t-1}+w_{t-2}+w_{t-3}+w_{t-4}}{4}$. We use the moving average in equation (5) in order to smooth the transition between regimes. We estimate the threshold model by maximum likelihood and get the optimal threshold (-9.54). Thus we define that the economy is in a low regime when $\widetilde{w}_t \leq -9.54$, otherwise the economy is in a high regime. As figure 3 shows, the low regime comprises mostly of the beginning of the sample starting in March 1984 through June 1985 and from September 1986 to March 1997, remaining dates are related to a high regime of the economy. The definition of this periods make sense with the previous discussion, because June 1997 is identified by the CMR test as a breakpoint and by Arango et al. (2012) as the beginning of the economic crisis. Moreover, the main economic changes previously discussed, which are a possible sources of change of regime, have affected mainly the last two decades.

[8] We select two regimes, given that the likelihood ratio test for the existence of three regimes was rejected at standard significance levels.
[9] Similar regimes are obtained using the moving average of order five and six for the cointegration equation.

FIGURE 3: REGIMES

1984q1-2016q4



Source: Author´s calculation

Figure 3 presents the regimes and its dates, the red area corresponds to the periods where $\widetilde{w}_t > \gamma$ and the white zones where $\widetilde{w}_t \leq \gamma$.

Table 5 presents TVEC model estimate for two regimes and three lags. The first two columns present the model under the low regime and the last two columns present the response under the high regime. The speed of adjustment is higher in the high regime than in the lower (-0.00008 vs -0.00003). However, it is lower than the estimate from the standard VECM model (-0.00015). The model is not miss specified as the residuals are normally distributed and free of serial autocorrelation (see Table 3 of appendix III).

TABLE 5: ESTIMATES OF A TVEC MODEL WITH ONE TRESHOLD

Quarterly data

Cointegrating Equation

GDP_{t-1}	1.00
UR_{t-1}	35.60
Constant	-24.31

Error Correction Model

	Low Regime		*High Regime*	
	GDP	*UR*	*GDP*	*UR*
α	-0.00122***	-0.00003	-0.0004***	-0.00008
	(0.00024)	(0.00015)	(0.0005)	(0.0003)
ΔUR_{t-1}	-0.550**	-0.126	-0.075	0.102
	(0.25)	(0.15)	(0.32)	(0.19)
ΔUR_{t-2}	-0.613**	-0.007	0.290	0.007
	(0.25)	(0.15)	(0.33)	(0.20)
ΔUR_{t-3}	-0.558**	0.189	0.266	0.051
	(0.25)	(0.02)	(0.33)	(0.20)
ΔGDP_{t-1}	-0.877***	-0.036	0.892	-0.065
	(0.15)	(0.09)	(0.19)	(0.11)
ΔGDP_{t-2}	-0.281	-0.032	0.424**	-0.051
	(0.18)	(0.11)	(0.22)	(0.13)
ΔGDP_{t-3}	-0.052	0.005	-0.028	-0.001
	(0.15)	(0.09)	(0.18)	(0.11)

Standard deviation in brackets

* p<0.10, ** p<0.05, *** p<0.01

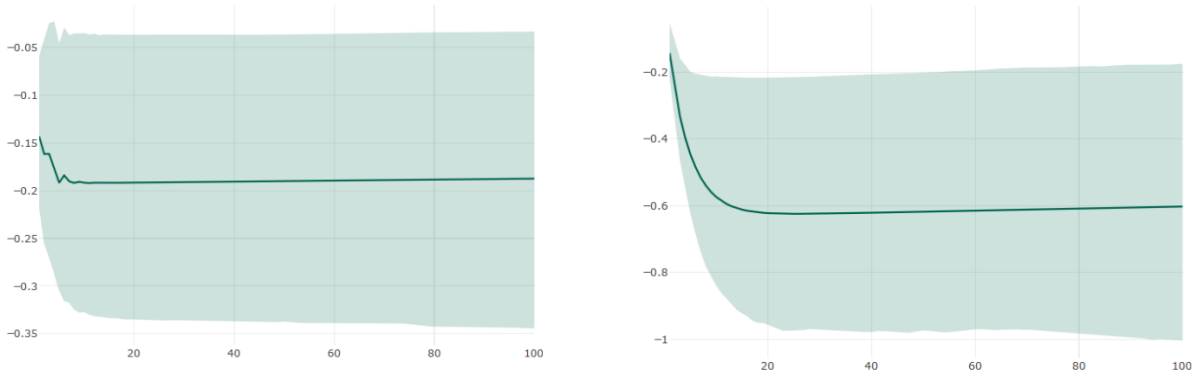
Note: Table 5 presents the Okun's law coefficients for Colombia using a TVEC (3). For the estimation was taken into account a sample from 1984q1 to 2016q4. For the estimation of the TVEC was used an intercept (no trend) in CE - no intercept in VAR. The percentage of sample in each regime is 35.1% and 64.9%. Threshold value was -9.536239.

Figure 4 presents the impulse response of the UR under both regimes. Panel A presents the response of the UR to a 1% increase in GDP under the low regime, while Panel B presents the response under the high regime. Then under the high regime an increase on 1% in GDP reduces the unemployment rate by 0.6 pp after eighteen quarters (4.5 years). The main response is given in the first two years, where the unemployment rate is expected to decrease by 0.4pp in the first year and 0.14 in the second year. The rest of the ajustment (around 0.06pp) is given in the following two

and a half years. Under a low regime the response is 0.19 pp after eight quarters, where the main response is given in the first year (around 0.17pp). Notice that under the low regime the adjustement to the new equilibrium is faster, eventhough there is a lower speed of adjustment. While in the high regime the speed of adjustment is high it takes eighteen quarters to reach the new equilibrium.

We have mentioned that the high regime is caracterized by important institutional changes in the labor market, which may produce a more flexible labour market. However, these institutional changes have not been enough to translate labor market flexibility into price flexibility. The flexibility on the labour market should imply better ajustment to the negative shocks, through prices more than through quantities. However, the results show that the response of the UR to a shock in the GDP is higher than it should be in a flexible labor market. The reason is the low flexibility of prices which implies a high response to unemployment. As is reported by some authores, there is evidence of high stickness of prices in Colombia during the period 1999 to 2008 (see Julio et al. (2009)).

FIGURE 4: IMPULSE RESPONSE OF THE UR
1984q1-2017q2



Note: Figure 4 presents the response of the unemployment rate to 1% growth of the quarterly GDP of the TVEC model of table 5.

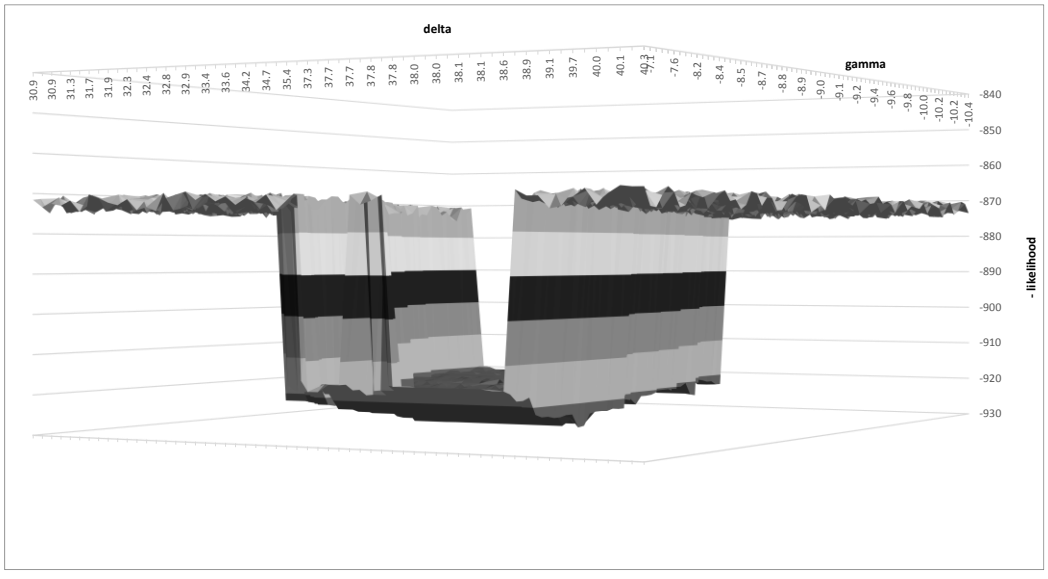
Since 2015 the colombian economy has received a negative shock in the commodity prices that has been translated in a reduction of GDP growth of around 1% during 2015 and during 2016. The first negative shock in 2015 produced an estimated increase in the TD of around 0.54pp during the first two years, which taking into account the negative shock of 2016, would imply an increase of 0.94pp according to the results of the TVECM model. Comparing the observed data of TD (7 main cities in Colombia) since 2015, the increase since the shock has been of around to 1pp (from december 2015 to september 2017), which is not very different from the model estimation (0.94pp).

3.4 Robustness Analysis

The TVECM estimated in this paper has two regimes, and uses the moving average of order four of the error correction model to identify the regime. Although this criterion differs from Balke and Fomby (1992) it allows us to capture a more stable and accurate estimation. Moreover, as the authors recommend we assume a cointegrating vector stable over both regimes. This implies that the long-run coefficients obtained from the lineal model reported in Table 2 are the same in the TVECM. However, we allow for the short-run and speed of adjustment to vary across regimes. However, to guarantee that the estimated TVECM minimizes the negative log-likelihood criterion (MLE) and a unique identified threshold, we build a grid search over the two-dimensional space (δ, γ), as proposed by Hansen and Seo (2002). The grid search for both parameters is created using up to three standard deviations for the δ estimated. The grid for the threshold (γ) is selected using the order four moving average of the error correction model.

Finally, for each possible model combination (δ,γ), we consider those which satisfy a minimum of 10% observations in each regime. After that, we examine the negative log-likelihood (Figure 5). The figure height presents the negative of the log likelihood focusing evaluated at the different combinations of the parameters that we want to maximize, and the constant is fixed to the estimate from the cointegration equation.[10] As we can see there is evidence of the existence of a threshold, which is confirmed from the likelihood ratio that rejects a standard VEC model in favor of a TVECM, the value of the threshold that maximizes the likelihood function is found at (-9.53).

Figure 5: Inverse of the likelihood function with one threshold



[10] We also analyze a third-dimensional grid including the constant, which led to similar results.

4. FINAL REMARKS.

This paper estimates a non-linear cointegration model (TVEC) that seems to be the best empirical specification to capture the Okun´s Law in Colombia from 1984-2017. Following the traditional literature we estimate the first-differences model, which suggests that an increase of 1% in the quarterly growth of the GDP reduces unemployment rate by 0.12 pp, while a 1% increase in the annual growth reduces unemployment rate by 0.40 pp. We also estimate the GAP specification where the OL coefficients range from -0.35 pp to -0.44 pp. These results are similar to previous findings estimated for Colombia (see González (2002), DANE (2006), Guillén (2010), Páez (2013), Cuervo y Mondragón (2016)).

A lineal and non-linear cointegration approach has not been used before in Colombian case to estimate the OL. Results from a lineal VECM estimation, show that after 1% increase in the GDP, the unemployment rate is reduced by 0.45 pp after sixteen quarters. However, according to our results, a non-linear cointegration approach (TVECM) seems to be a better empirical approximation. We estimate two-regimes in relation to the moving average of order four of the error-correction term. We find evidence of a higher response in the current regime (high regime), than in the lower regime. Under a high regime, an increase of 1% in GDP reduces the UR by 0.6pp after eighteen quarters (4.5 years), while in the low regime the response is 0.19 pp after eight quarters (2 years).

We define the high regime as a regime that has been characterized by important transformations in the Colombian labor market. During the last two decades, several aspects of the labor market have changed: *i)* changes in the regulation that modify the direct cost of hiring and firing workers, *ii)* increase in matchng efficiency between firms and workers, due to the introduction of technology information systems, and private and public employment agencies, such as the *Servicio Publico de Empleo, iii)* major incentives for the creation of small and medium size firms, which nowadays are one of the main sources of employment growth and (Flórez et al (2017)), *iv)* change of the role of minimum wage as being less important determinant of the natural unemployment rate or the unemployment rate in Colombia (see Arango, et al. (2016, 2017))[11], *v)* finally, after the economic crisis of the late nineties, and the openness to international trade, there was an increase on the introduction of temporary contracts that allowed firms to respond in a more flexible way to economic crisis and to be able to compete internationally (Heckman and Pagés (2004)).

All these changes in the labor market across the last two decades might have changed the relation between UR and GDP across time, making the labor market more flexible. Some evidence of this flexibility in the labor market is reflected the increase of worker mobility across estates (employment, unemployment and non-participant) found by Lasso (2013) as well as the growth in

[11] Arango et al. (2017) show that an increase on the minimum wage have a positive effect on the informality but not a significant effect on the unemployment.

churning and workers reallocation rates in Colombia for the period 2009-2015 found by Flórez, et al. (2017) and Morales and Medina (2016).

We have mentioned that the high regime is caracterized by important institutional changes in the labor market, which may imply a more flexible labour market. However, these institutional changes have not been sufficient to translate labor market flexibility into price flexibility. The flexibility of the labour market should imply a better ajustment to negative shocks through prices more than quantities. However, the results of the TVECM model show that under a high regime the response of the UR to a shock in the GDP is higher than it should be in a flexible labor market, where the ajustment should be given by reduction/increase on wages instead of increase/reduction of unemployment. The reason is the low flexibility of prices (Julio et al. 2009), which implies a high response through unemployment.

Since 2015 the colombian economy has received a negative shock in the commodity prices that has been translated into a reducción of GDP growth of around 1% during 2015 and during 2016. According to the TVECM model these two negative shocks would imply an estimated increase in the TD of around 0.94pp after the two previous years. However, since 2015, the increase in the TD (seven main cities) has been of around 1pp (from december 2015 to september 2017). Even though, the final effect would be observed in the next two years.

The estimation of a non-linear cointegration model of the Okun Law in the case of Colombia produces very usefull and interesting results that call for further research. The results of the paper are usefull for policy makers to forecast the response of the unemployment rate under a negative shock to the GDP, as has been the case with the current (2015-2017) slowdown of economic growth. Given the atipic historical behavior of the colombian unemployment rate, more non-linear methodologies can be implemented in order to improve our knowledge of labour market dynamics, and explore the change in the relation between the unemployment rate and the GDP growth.

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APPENDIX I

TABLE 1: UNIT ROOT TESTS.

		Dickey-Fuller		KPSS	
Variable	Deterministic components	5% Critical Value	Test Statistic	5% Critical Value	Test Statistic
		Levels*			
GDP	None	-1.95	3.59	0.15	0.27
Unemployment Rate	None	-1.95	-0.63	0.15	0.31
		Differences*			
GDP	None	-1.95	-1.97	0.15	0.11
Unemployment Rate	None	-1.95	-3.02	0.15	0.14

Table 1 presents the unit root tests for the Gross domestic product (PIB) and the seasonally adjusted unemployment rate. The first two rows show the test for the levels of series and the last two for the first diferrences. The first and second columns show the critical value and the test statistic under the Augmented Dickey- Fuller test while the third and fourth refer to the KPSS test. We are taking into account five lags in each case.

APPENDIX II

TABLE 1: ENGLE-GRANGER COINTEGRATION TEST.

	***Tau*-statistic**		***Z*-statistic**	
	Value	***p*-value**	**Value**	***p*-value**
Real GDP-Unemployment rate	-2.355	0.350	-32.789	0.002
Number of observations	119	119	119	119

Table 1 presents the Engle-Granger Cointegration Test for the Gross domestic product (PIB) and the seasonally adjusted Unemployment rate. The first and second columns show the Tau and Z-stastic, while the first row presents the results of the test. The automatic lag-legth selection was used with Schwarz Information Criterion.

TABLE 2: PHILLIPS – OULIARIS COINTEGRATION TEST.

	***Tau*-statistic**		***Z*-statistic**	
	Value	***p*-value**	**Value**	***p*-value**
Real GDP-Unemployment rate	-2.169	0.442	-9.650	0.371
Number of observations	119	119	119	119

Table 2 presents the Phillips-Ouliaris Cointegration Test for the Gross domestic product (PIB) and the seasonally adjusted Unemployment rate. The two first columns show the Tau and Z-stastic, while the first row presents the results. We use a non-prewhitened Bartlett Kernel with a fixed Newey-West bandwidth.

APPENDIX III

TABLE 1: ZIVOT-ANDREWS UNIT ROOT TEST

Variable	Deterministic components	5% Critical Value	Test Statistic	Breakpoint
		Levels*		
UR	Constant	-4.80	-3.82	1995q2
	Trend	-4.42	-2.90	2000q3
	Both	-5.08	-4.38	1997q4
GDP	Constant	-4.80	-5.48	1998q3
	Trend	-4.42	-2.63	2001q4
	Both	-5.08	-5.71	1998q3
		Differences*		
UR	Constant	-4.80	-6.03	2001q2
	Trend	-4.42	-4.81	1996q4
	Both	-5.08	-6.19	2001q2
GDP	Constant	-4.80	-6.05	2002q2
	Trend	-4.42	-5.16	1998q4
	Both	-5.08	-6.06	2002q2

Table 1 presents the Zivot-Andrews Unit Root tests for the Gross domestic product (PIB) and the seasonally adjusted unemployment rate. The first six rows show the test for the levels of the series and the last six for the first differences. The first column describes the deterministic component used. Second and Third columns show the critical value and the test statistic while the fourth refers to the date where there is a structural breakpoint. We take into account five lags.

TABLE 2: PERRON-VOGELSANG UNIT ROOT TEST

Variable	Specification	5% Critical Value	Dummy u1	(rho-1)	Breakpoint
		Levels*			
UR	AO	-3.56	6.07	-1.45	1994q3
	IO	-4.27	2.25	-2.59	1994q4
GDP	AO	-3.56	18.72	-2.35	2004q4
	IO	-4.27	3.40	-3.16	2002q4
		Differences*			
UR	AO	-3.56	-0.75	-5.44	1998q3
	IO	-4.27	-1.31	-3.74	1998q4
GDP	AO	-3.56	-0.77	-5.90	1998q2
	IO	-4.27	0.06	-6.99	1998q3

Table 2 presents the Perron-Vogelsang Unit Root tests for the Gross domestic product (PIB) and the seasonally adjusted unemployment rate. The first four rows show the test for the levels of the series and the last four for the first differences. The first column describes specification used, additive outlier (AO) or innovational outlier (IO). Second and Third columns show the significance of structural change. The last column refers to the date when there is a structural breakpoint. We used five lag for the test.

TABLE 3: RESIDUAL TEST TVEC

Test	*p-value*
JB - Normality Test	0.2923
Autocorrelation Test	0.2156
ARCH Test	0.1192

Note: Hansen and Seo Test (2006): Tests the null of linear cointegration against threshold cointegration following Hansen and Seo (2002)


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