Why the Effects of Deregulations in Natural Gas Market in U.S. is Failing in lower prices?

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Abstract

This paper put forward contrary hypothesis to the well-established argument that –the natural gas markets have become more efficient (De Vany & Walls, 2017; Joskow, 2013; King & Cuc, 1996; Olsen, Mjelde, & Bessler, 2015; Park, Mjelde, & Bessler, 2007; Walls, 1994a, 1994b). I provide statistical evidences that the intended effects of natural gas market deregulations and reforms (long run price converges) is becoming weak and open the discussion floor to answer why the effects of deregulation in natural gas market in U.S. is failing. As opposed to the fully efficient market hypothesis (E. Fama, 1965; E. F. Fama, Fisher, Jensen, & Roll, 1969) and the impossibility of efficient market hypothesis (Grossman & Stiglitz, 1980), I show that the natural gas markets tend to incline toward adaptive market hypothesis to thrive and evolve through the competition, adaptation, and natural selection (Lo, 2004). Hence, the natural gas markets show the mixed signal on long run price convergence or law of one price.

1. Introduction

To promote efficiency in natural gas market through market competition, the Natural Gas Policy Act of 1978 (NGPA) by the Federal Energy Regulatory Commission (FERC) progressively deregulated the natural gas sector in United States during 1980s and 1990s (Cuddington & Wang,

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2006). These reforms were strategic: a) “to guarantee ‘open access’ to all market participants on a nondiscriminatory basis” (Cuddington & Wang, 2006) and b) to “decouple the production and trading of the commodity natural gas” which is a very homogeneous product “from its transportation” (Cuddington & Wang, 2006) which varies spatially. The deregulation processes[2] led establishment of several natural gas spot markets in U.S. Most of these establishments situate at the major pipeline intersections and within the major production regions.

Further, allowing such free intercourse among buyers and seller for a homogenous good should have stronger tendency for the spatial price convergence. And, for the reforms to be successful, the markets should integrate. One of the proxy for market integration is the existence of Law of One Price[3] (LOOP) in long run equilibrium. There are several evidences that after these reforms, the natural gas markets have become more efficient (De Vany & Walls, 2017; Joskow, 2013; King & Cuc, 1996; Olsen et al., 2015; Park et al., 2007; Walls, 1994a, 1994b). Most of these studies test the existence of co-integrating relationship among the prices[4] of various natural gas markets and granger causality.

Even thou, previous studies point toward the direction of markets being efficient but are inconclusive. This can mainly due to their approach of testing Granger Causality of auto-regressive (AR-GC) model. As an alternative, this paper presents state-space Granger causality (SS-GC) approach which is in general more computationally efficient and numerically stable than AR-GC

[2] The reviews of historical derogations time-line can be found in (Joskow, 2013).
[3] The law of one price states the prices of homogenous goods across different locations differ by at most impediments of arbitrage including transaction/transportation costs (Olsen et al., 2015).
[4] The market demand and supply conditions drive the natural gas prices. The disparities of production, net export and storage of domestic natural gas drives supply-side while volatile weather, economic condition, demographics and other energy related sector drives the demand-side (FERC, 2015).

(Barnett & Seth, 2015). Further, previous studies do not analyze how the prices among regional markets are discovered in short-run to converge in the long-run equilibrium of LOOP is failing.

Contrary to previous study, this study contributes on the state-space causal analysis of short-run price discovery and claims that the long-run price convergences among of eight different regional natural gas markets of U.S. and Canada is failing apart. This paper first testifies the claim and opens a broader discussion on why the anticipated effect of deregulation in Natural gas is falling apart.

This study retrieves weekday natural gas spot prices from January 1, 1994 to October 31, 2016 from Bloomberg L.P. (2017). The eight regional natural gas markets are: (1) AECO Hub, Alberta, Canada; (2) Chicago City Gate, Illinois; (3) Dominion South Point, Pennsylvania; (4) Henry Hub, Louisiana; (5) Malin, Oregon; (6) Oneok, Oklahoma; (7) Opal, Wyoming and (8) Waha Hub, Texas. These prices are calculated as volume-weighted average price in dollars per MMbtu for gas delivered the next day. The missing values are imputed with previous day's prices. The prices, there were transformed in natural log.

2. Model and hypothesis

2.1 The state-space representation

These prices of regional market are discrete-time, real-valued vector stochastic process $\mathbf{y}_t = [y_{1t}, y_{2t}, \cdots, y_{nt}]$, $-\infty < t < \infty$, of observation, where, i is indexed for each market such that $n = 8$. The general time-invariant state-space model without input for the observation process $\mathbf{y}_t$ is:

$$\mathbf{x}_{t+1} = A\mathbf{x}_t + \mathbf{u}_t \tag{0.1}$$

$$\mathbf{y}_t = C\mathbf{x}_t + \mathbf{v}_t \tag{0.2}$$

The equation (1.1) is the state transition equation and (1.2) is the observation equation, where $\mathbf{x}_t$ is an $m-$dimensional state (unobservable) variable, $\mathbf{u}_t$ and $\mathbf{v}_t$ are zero-mean white noise process. C is the observation matrix and A is the state transition matrix. If $C \to 1$ represents market begin more efficient and integrated hence the prices converges spatially (see (King & Cuc, 1996; Nepal & Jamasb, 2012)). The parameters of the above model are A, C, Q, R, S where,

$$\begin{bmatrix} Q & S \\ S^T & R \end{bmatrix} = E\left[\begin{bmatrix} \mathbf{u}_t \\ \mathbf{v}_t \end{bmatrix}\begin{bmatrix} \mathbf{u}_t^T & \mathbf{v}_t^T \end{bmatrix}\right] \tag{0.3}$$

The (1.3) is the noise covariance matrix. We assume $\mathbf{x}_t$ and $\mathbf{y}_t$ are weakly stationary process such that maximum of the absolute value of eigenvalues of A is below unit i.e. $\lambda_{\max}(A) < 1$. We assume R is a positive-definite. A process $\mathbf{y}_t$, hence is a stable state-space model which also satisfies a stable $ARMA$ process.

Given, such state-space model, we can define $\mathbf{z}_t$ as the expectation of unobserved or state variable $\mathbf{x}_t$ conditional on the past prices of market $\mathbf{y}_{t-1}^-$ i.e. $\mathbf{z}_t = E\left[\mathbf{x}_t \mid \mathbf{y}_{t-1}^-\right]$ where $\mathbf{y}_{t-1}^- \equiv \left[\mathbf{y}_{t-1}^T, \mathbf{y}_{t-1}^T, \cdots,\right]^T$ then the innovations $\boldsymbol{\varepsilon}_t \equiv \mathbf{y}_t - E\left[\mathbf{x}_t \mid \mathbf{y}_{t-1}^-\right]$ is white-noise process with positive-definite covariance matrix $\Sigma = E\left[\boldsymbol{\varepsilon}_t \boldsymbol{\varepsilon}_t^T\right]$. For the new state variable $\mathbf{z}_t$, the state-space model for $\mathbf{y}_t$ is redefined as:

$$\mathbf{z}_{t+1} = A\mathbf{z}_t + K\boldsymbol{\varepsilon}_t \tag{0.4}$$

$$\mathbf{y}_t = C\mathbf{z}_t + \boldsymbol{\varepsilon}_t \tag{0.5}$$

The K is the Kalman gain matrix which updates the model for each iteration. The state equation of (1.5) can be expresses as $\mathbf{z}_t = (I - A\gamma)^{-1} K\gamma \bullet \boldsymbol{\varepsilon}_t$ where γ represents the back-shift operator, which yield an MA representation for the observation process with the transfer function $H(\gamma)$ such that $\mathbf{y}_t = H(\gamma)\boldsymbol{\varepsilon}_t$. The $H(\gamma) = I + C(I - A\gamma)^{-1} K\gamma$. The (1.4) can be expressed as $\mathbf{z}_{t+1} = B\mathbf{z}_t + K\mathbf{y}_t$ with $B \equiv A - KC$ which derives and AR process such that $B(\gamma)\mathbf{y}_t = \boldsymbol{\varepsilon}_t$ where $B(\gamma) \equiv I - C(I - B\gamma)K\gamma$ and $B(\gamma) = H(\gamma)^{-1}$. Given $\lambda_{\max}(B) < 1$, the cross-power spectral density of $\mathbf{y}_t$ can be factorize on $|\gamma| = 1$ as:

$$S(\gamma) = H(\gamma)\Sigma H^*(\gamma) \tag{0.6}$$

2.2 Granger causality

Granger causality is expressed as prediction error. Suppose the observable process (the regional prices) $\mathbf{y}_t$ is partitioned into sub-process $\mathbf{y}_t = \left[\mathbf{y}_{1t}^T, \mathbf{y}_{2t}^T, \mathbf{y}_{1t}^T\right]$. Then, given the observable information, the granger causality from $\mathbf{y}_{2t}$ to $\mathbf{y}_{1t}$ condition on $\mathbf{y}_{3t}$ quantifies the extent to which the past of $\mathbf{y}_{2t}$ improves the prediction of the future of $\mathbf{y}_{1t}$ over the extent of $\mathbf{y}_{1t}$ (along with $\mathbf{y}_{3t}$) already predicts its own future. The conditional grange causality from $\mathbf{y}_{2t}$ to $\mathbf{y}_{1t}$ condition on $\mathbf{y}_{3t}$ can be expressed as:

$$F_{y_2 \to y_1 | y_3} \equiv \ln \frac{\left|\Sigma_{11}^R\right|}{\left|\Sigma_{11}\right|} \tag{0.7}$$

If the $\mathbf{y}_{3t}$ is empty, then above granger causality give unconditional granger causality from $\mathbf{y}_{2t}$ to $\mathbf{y}_{1t}$.

2.3 Hypothesis

Hypothesis-1

If each of the natural gas market are efficient, then market should reflect all the private and public information to their prices such that each market individually should follow a random walk process and the market should be unpredictable Fama (1965). To fail to reject (accept) this hypothesis, the prices of each market should be non-stationarity. I hypothesis that each natural gas market has evolved from being efficient to less efficient. To test, I implement the Augmented Dickey Fuller unit root test (A. Dickey & A. Fuller, 1979). Rejection of the null hypothesis of ADF, will support my hypothesis. In other word, if p-value approaches to zero, will support my hypothesis of each market individually becoming less efficient to reflect the information on their prices.

Hypothesis-2

If the markets are jointly efficient, then markets should follow the law of one price or the prices on spatially differentiated market should converge to same price. I hypothesis that the law of one prices are becoming weak. To test this hypothesis, I implement the multivariate Johansen test of cointegration (S. Johansen & Juselius, 1990; Soren Johansen, 1991; Søren Johansen, 1988). If the trace statistics fails to reject the null hypothesis of no-cointegration will align on my hypothesis.

Hypothesis-3

The market is prone to unobservable factors. For that, I implement the state-space model with Kalman filter (Barnett & Seth, 2015). If the market is fully integrated, then coefficient vector C from (1.2) should be unit. If the coefficient vector C gradually becomes less than unit will prove my hypothesis that market is failing to become the efficient. This also shows that the intended effects of deregulation are failing.

Hypothesis-4

If the markets are efficient and fully integrated, then there should be no scope of price discovery. I hypothesis that there exist opportunities of the price discoveries in the markets. To test this hypothesis, markets should fail to reject the conditional and unconditional granger non-causality hypothesis (Barnett & Seth, 2015).

3. Results

The Table-1 shows the descriptive statistics.

Table 1: Descriptive statistics

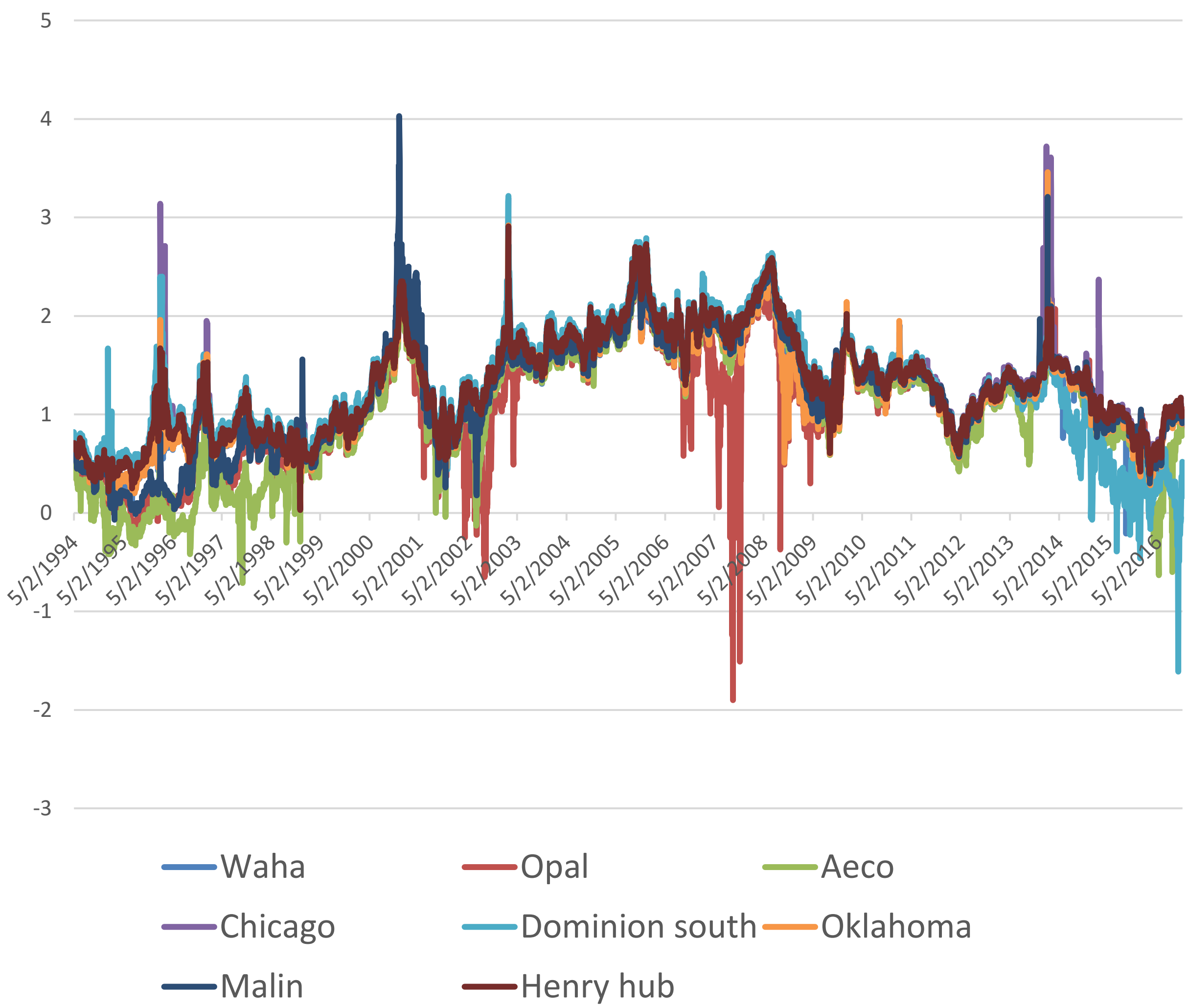
Markets	Mean	Median	Max	Min	Std dev	Skew	Kurt
Waha	3.90	3.46	24.50	0.81	2.08	1.42	7.26
Opal	3.47	3.16	28.98	0.15	1.98	0.74	8.00
Aeco	3.46	3.15	15.18	0.49	2.16	0.41	3.78
Chicago	4.29	3.74	41.07	1.23	2.46	3.03	23.15
Dominion	4.30	3.59	25.00	0.20	2.57	1.87	7.16
Oklahoma	3.85	3.39	31.79	1.06	2.05	1.51	10.60
Malin	3.98	3.55	56.25	0.93	2.53	3.62	46.45
Henry hub	4.20	3.65	18.41	1.03	2.32	1.85	6.77

N=5871

3.1 Trend diagram

The Figure-1 represents the trend diagram. All the market tends to follow similar trend patter however, there are certain time where the market diverges. The prices in the market prior to 1999, 2002 to 2003, 2006 to 2009 and post 2013 seems not to follow the law of one prices. These divergences can mainly due to certain events like extreme economic conditions, policy uncertainties which affects either or both market demand and supplies.

Figure 1: Trend diagram of log of spot prices of natural gas markets



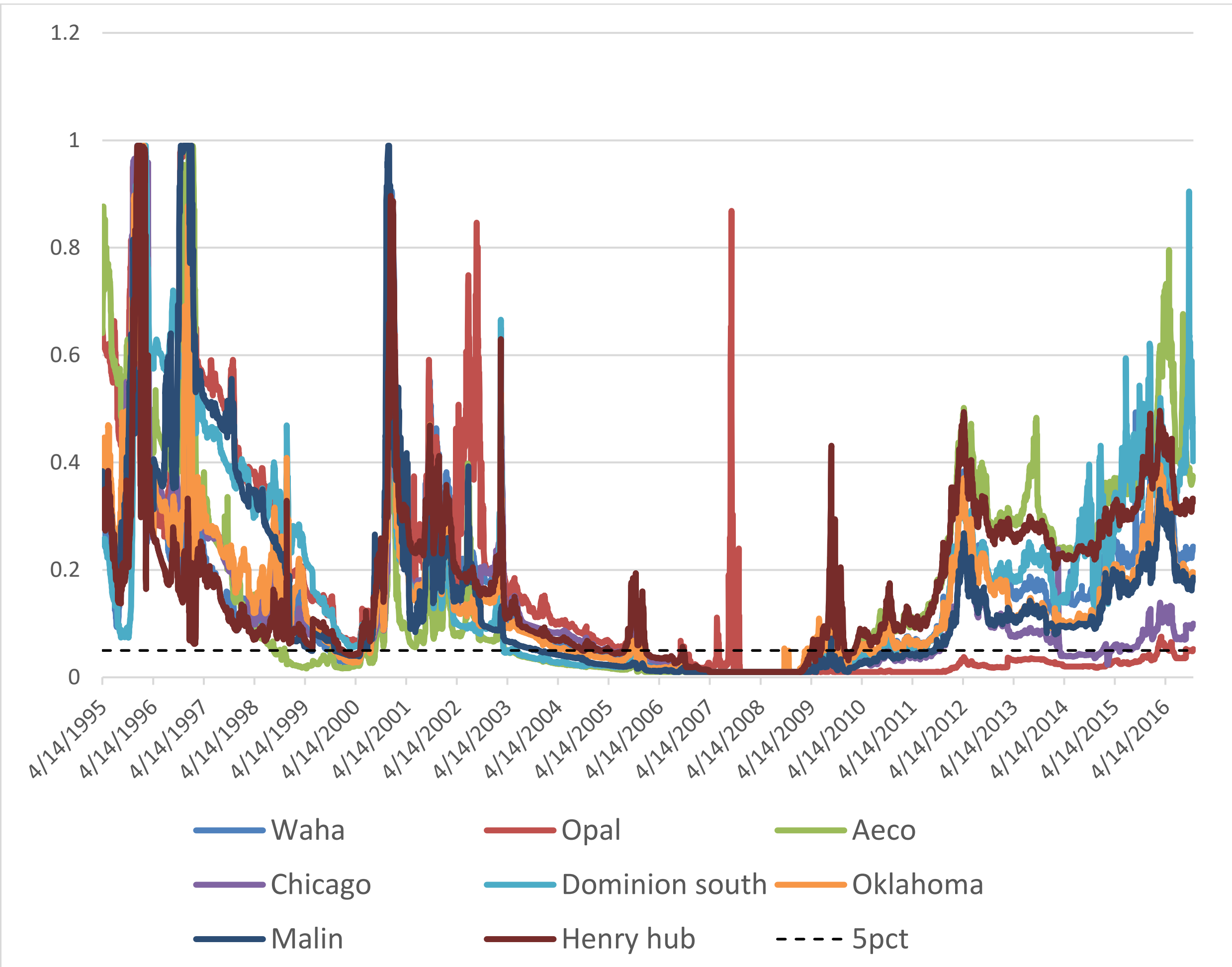
3.2 Recursive unit root test

The Figure-2 shows p-value of 250[5] and forward recursive rolling widow Augmented Dickey Fuller unit root test (A. Dickey & A. Fuller, 1979). If the p-value are above 5%, then we fail to

[5] The 250 weekdays roughly account a year.

reject the null hypothesis of non-stationarity. If the series are non-stationary, then the mean, variance and covariance of series evolve over the time. This also represents prices tend to follow random walk which represents that market is becoming efficient such that it follows the efficient market hypothesis.

Figure 2: 250 days recursive ADF unit root



As in the Figure-1, Figure-2 also shows that market started to become stationary in post 1997 till dawn of 2000 and 2003 to 2009. However, post 2009, seems market to violate the law of one prices.

3.3 Test of co-integration

I tested the existence of cointegration or not following the trace test of Johansen test of cointegration (S. Johansen & Juselius, 1990; Soren Johansen, 1991; Søren Johansen, 1988). The null hypothesis for the trace test is that the number of cointegration vectors is $r=r^*<k$, vs. the alternative that $r=k$, where k is the number of variable. I have tested the 250-period rolling ADF test in the first difference of price (results not reported). For each market, for each rolling period, the null of hypothesis of non-stationarity is rejected. This leads to conclude that the series are integrated of order one, thus usual test of cointegration can be applied[6].

There are 8 different prices of natural gas market. Hence under the null hypothesis of the trace test of Johansen test, I tested if there exist no cointegration, if there exists one or less, if there exist two or less cointegration and so on till if there exist seven or less cointegrating relation. Given, the market to be fully integrated, we would expect fail to reject the null hypothesis of seven or less cointegrating relationship. If the markets don't follow law of one price or don't co-move together we would expect fail to reject the null of zero cointegration. These tests are implemented with 250 days and forward recursive rolling widow. The figure related on the test of cointegration are provided in appendix

The test of the number of cointegration is sever or less is failed to be rejected (in Figure-3) as the trace statistics is less than 10% critical value. This represents no existence of seven cointegration or the market is not fully integrated. It's very consistent post 1998. Hence at least, one among eight markets don't comove. Similarly, the test of the number of cointegration is six or less represented in Figure-4. During 2005 until mid of 2013, the test statistics is greater than 1% critical value. This

[6] If series are integrated of order 2, follow chapter-2 of Johansen, Søren (1995), Likelihood-based Inference in Cointegrated Vector Autoregressive Models. Oxford University Press.

suggest failure to reject the null hypothesis of existence of six or less cointegrations. Therefore, it represents, during that period at least two markets were not comoving. While rest of the figures (Figure-5 to Figure-10) strictly reject the null of existence of five or less cointegration. This represents, at least, six among eight markets are cointegrated.

3.4 State-space model

3.5 Granger causality

4. Discussions: why the effects of deregulation in natural gas market is failing?

5. Conclusion

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Appendix

Figure 3: Number of cointegration vectors is seven or less

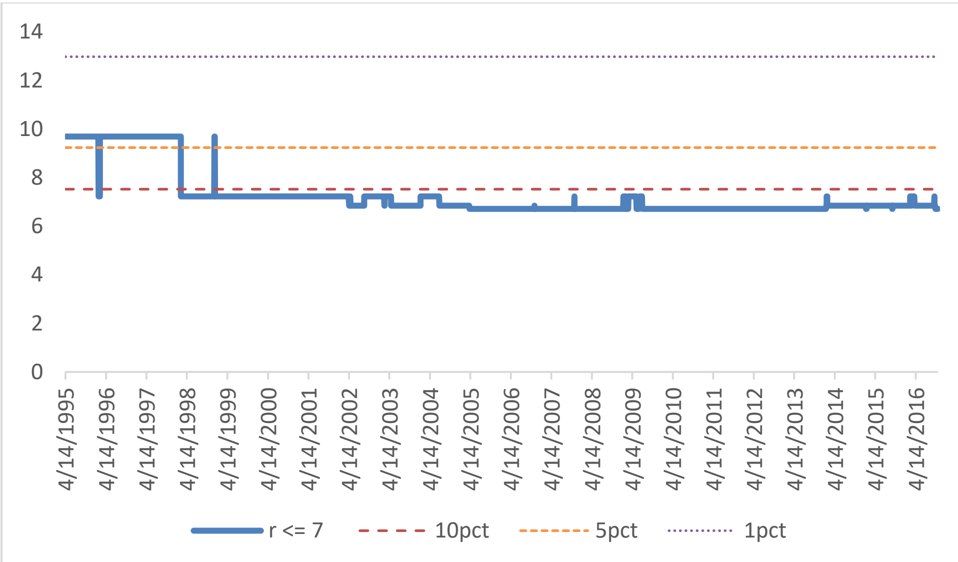

Figure 4: Number of cointegration vectors is six or less

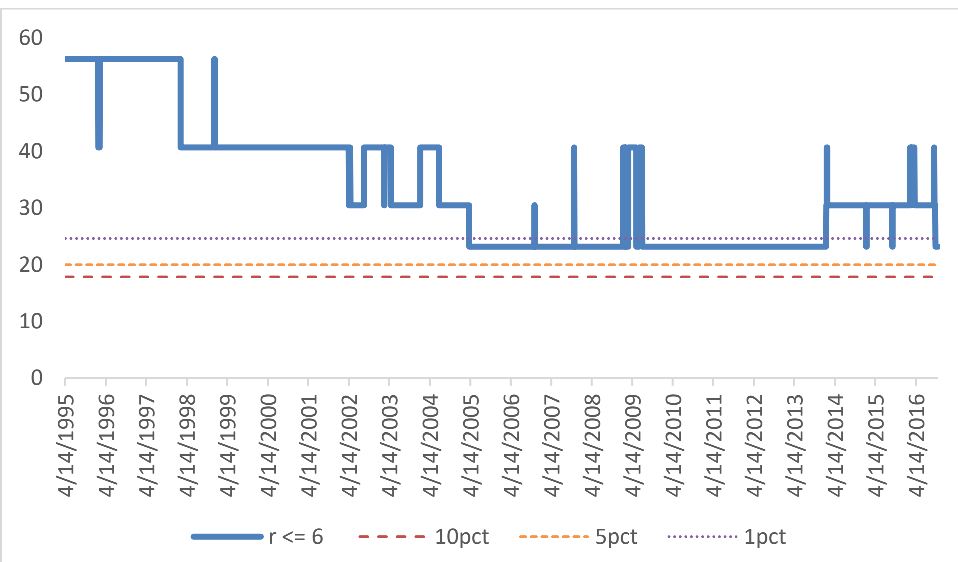

Figure 5: Number of cointegration vectors is five or less

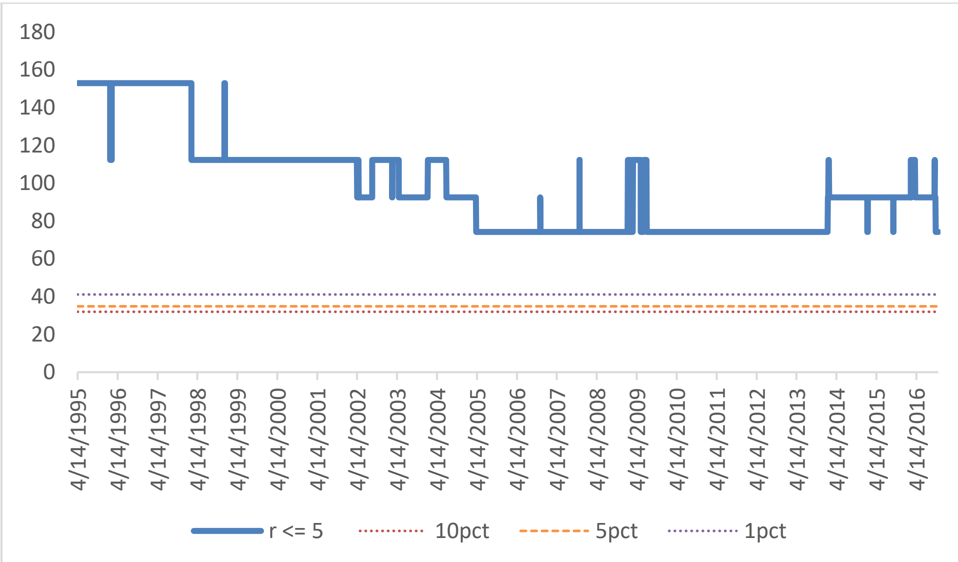

Figure 6: Number of cointegration vectors is four or less

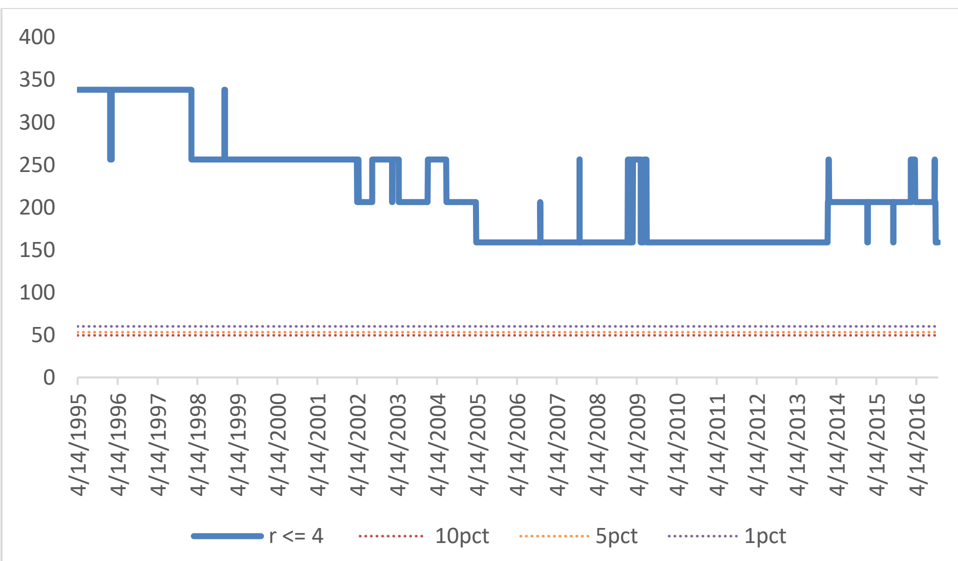

Figure 7: Number of cointegration vectors is three or less

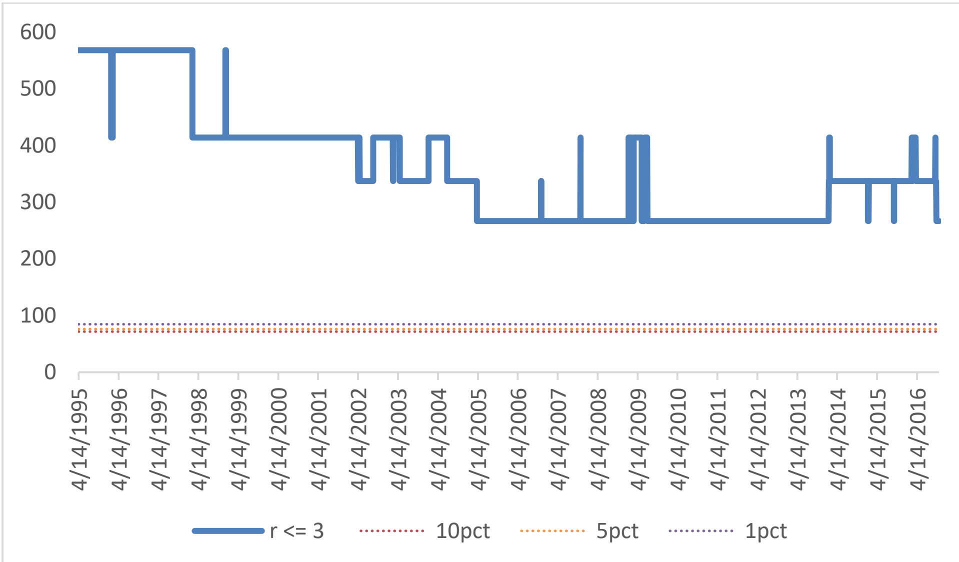

Figure 8: Number of cointegration vectors is two or less

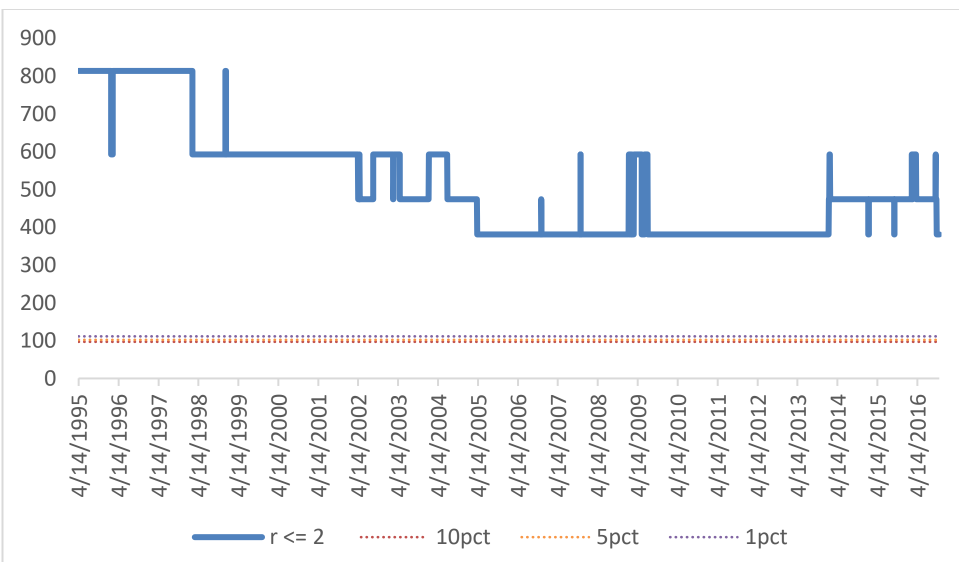

Figure 9: Number of cointegration vectors is one or less

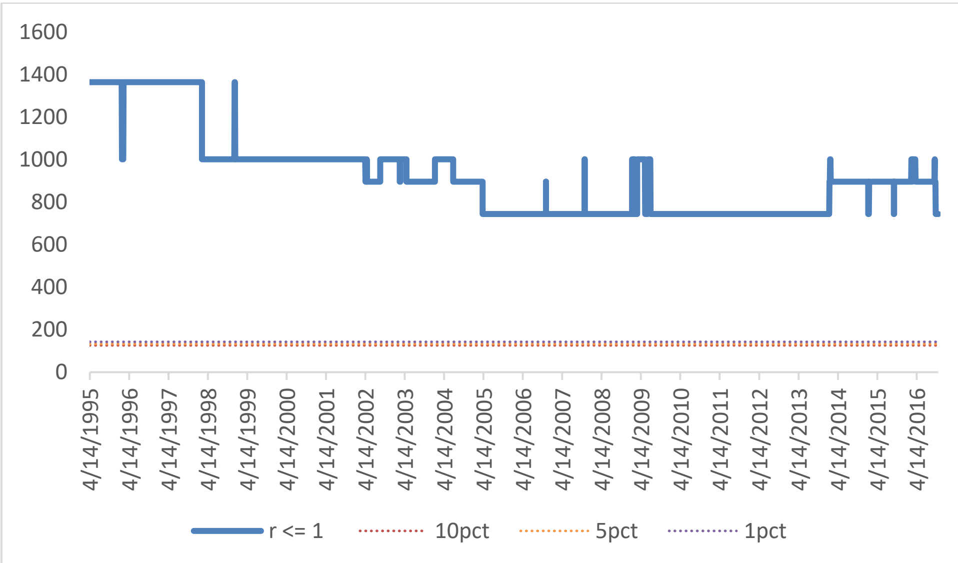

Figure 10: Number of cointegration vectors is zero