

## Impact of Climate Change on Energy in Saudi Arabia: An Application of the ARDL Bound Testing Approach

Farjallah Nadia<sup>1</sup>, Aftab Hussain Tabasam<sup>2\*</sup>, Raja Nowsharwan Sarwar<sup>3</sup>

<sup>1</sup>LaREMFIC Laboratory, IHEC, University of Sousse, Tunisia, nadiafarjallah25@gmail.com

<sup>2</sup>University of Poonch Rawalakot Azad Kashmir, Pakistan, aftabtabasam@upr.edu.pk

<sup>3</sup>MS Riphah International University Islamabad, Pakistan, nowsherwan1980@gmail.com

**Abstract:** Energy abundance is driving the global economy. But this comes at a price: our energies to extract energy from fossil fuels and renewable energy sources are costing us dearly in terms of land. The pollution generated by the production and consumption of energy, including the combustion of biomass, is changing the ecology of the entire planet. This study aims to analyze the contributions of renewable and non-renewable energies in Saudi Arabia to long-term global climate change. This study is based on the Auto-Regressive Distributive Lags (ARDL) approach that is proposed by Pesaran et al during the period 1990-2019. The empirical estimate yields interesting results. There is a relationship between climate change, renewable and non-renewable energy in the long term.

### 1. Introduction

In recent decades, the environmental degeneration caused by global warming has become a major concern for policy-makers and researchers alike. Energy generally comes from two types of natural resource: non-renewable (fossil and fissile) and renewable. Non-renewable resources are themselves of two types: fossil and fissile. Fossil resources are those derived from the decomposition of organic matter, mostly plant matter, over millions of years to produce mainly coal, oil and natural gas. Deposits of these non-renewable energy sources are depleted over time. Fissile resources are those derived from the fission of the atomic nucleus, mainly uranium. As these resources are depleted, they are still unable to satisfy consumer demand in all areas of daily life, and their production is declining at the same rate as oil. For this reason, they are also referred to as "stock energies", since their reserves are limited.

On the other hand, there is another type of natural resource, called renewable energy. These include solar thermal and photovoltaic energy, wind, tidal and river power, heat from the ground and subsoil, biomass and waste. These resources are called renewable energies because they are self-renewing after consumption. Moreover, energy is one of the major factors affecting not only economic growth, but also economic development, social well-being and ecology. It's clear that modern, industrialized societies are using more energy in a variety of areas: industry, commerce, agriculture, services, housing, transport, and so on. The effects of climate change will vary from one region of the world to another, affecting both energy production and demand. In Saudi Arabia, energy demand for air conditioning could rise sharply, due to the increased risk of heat waves. The impact of global warming on the flow and temperature of surface waters (rivers and coastal seas) could affect the cooling capacity of thermal or nuclear power plants. Changes in the water cycle (precipitation) and the melting of mountain glaciers could also affect hydroelectric power generation capacity. The capacity to renew biomass (which can be used to produce heat or biofuels) could also be affected by climate change and its interaction with changes in air quality.

There is considerable uncertainty about the evolution of small-scale events such as hurricanes or storms, to which energy production systems and power transmission networks are exposed. Saudi Arabia's energy sector<sup>1</sup> is dominant in Saudi Arabia's economy: around 87% of government revenues and 90%

---

<sup>1</sup> [https://fr.wikipedia.org/wiki/%C3%89nergie\\_en\\_Arabie\\_saoudite#:~:text=effet%20de%20serre-,Les%20%C3%A9missions%20de%20gaz%20%C3%A0%20effet%20de%20serre%20li%C3%A9es%20%C3%A0,France%20%3A%204%2C36%20t.&text=var.](https://fr.wikipedia.org/wiki/%C3%89nergie_en_Arabie_saoudite#:~:text=effet%20de%20serre-,Les%20%C3%A9missions%20de%20gaz%20%C3%A0%20effet%20de%20serre%20li%C3%A9es%20%C3%A0,France%20%3A%204%2C36%20t.&text=var.)

of export earnings came from the oil and petrochemicals industry in 2017, accounting for around 42% of Saudi Arabia's gross domestic product. Saudi Arabia's primary energy production is limited to two products: oil (87.5%) and natural gas (12.5%): the share of natural gas has risen sharply: from 5.3% in 1990 to 12.5% in 2019; in 29 years, energy production has increased by 74% (60% for oil and 311% for gas). Increasing the use of renewable energies is an essential strategy for mitigating climate change. Nevertheless, the sensitivity of renewable energies to climatic conditions means that the energy system's vulnerability to climate change may also become greater. The energy sector is known as a major cause of climate change (around two-thirds of global CO<sub>2</sub> emissions in 2018.<sup>2</sup>).

Various authors (Yalew et al., 2020, Cronin et al., 2018) concluded that there is a need for more in-depth knowledge of the impacts of climate change on the energy system as a whole and on a global scale. In addition, the uncertainty of climate change and the ability of the energy system to adapt to such impacts must be taken into account. Among renewable energies, energy and/or electricity production from PV and wind turbines is limited by weather conditions, such as solar radiation, cloud cover, wind direction and speed. Future climate change will modify these weather conditions. Some will increase, others decrease, and future renewable energy production will vary according to these changes. In this context, at the same time as renewable energies can mitigate climate change, they also suffer the consequences of climate change. In the same way that renewable energies can mitigate climate change, they also suffer the consequences of climate change.

These impacts on renewable energies will be unavoidable to some extent, even with strict mitigation policies. (GIEC, 2014a)<sup>3</sup>. Treut et al., 2007 link global warming and its consequences to human activities rather than natural fluctuations. The Earth's natural climate changes gradually over a long period of time (tens of thousands to millions of years). Climate change is recognized as an important issue, and the international communities, through the United Nations, have created special groups to focus on the effects of climate change and have launched protocols to organize a global response to deal with its consequences. Any change in solar input, the atmosphere or the hydrological cycle will affect interactions between the atmosphere, hydrosphere, cryosphere and biosphere. Climate change interacts with various natural processes in the atmosphere, hydrosphere, cryosphere and biosphere. There is growing evidence that anthropogenic gases are responsible for climate change (Treut et al., 2007). According to various authors (Rudolph & Figge, 2017 ; Cowan et al., 2014), the rate of carbon dioxide (CO<sub>2</sub>) emissions is a key factor in greenhouse gas emissions (GHG) and its consequent impacts on global warming, climate change, biodiversity, air quality and natural resources. Coupled with growing human consumption, this concern not only increases the vulnerability of societies, but also accentuates the scarcity of the earth's ecological resources. (Nathaniel, 2020; Rahman, 2020). With the industrialized world's current fast-paced consumption and production patterns, climate change is having a negative impact on ecosystems, species and humanity<sup>4</sup>. Energy transition is necessary to protect the environment in the face of climate change. A major energy transition is needed to achieve the goal of climate-neutral energy systems. The use of renewable energies appears as an alternative to conventional energy in this concept. The objective of this article is to analyze the impact of climate change on renewable and non-renewable Energy in Saudi Arabia. Is there a short- and long-term relationship between climate change and energy? To achieve this objective, we use the ARDL (Auto- Regressive Distributed Lags) model. The rest of the paper is structured as follows: the conceptual framework; data and variables; and the econometric model in section 1. Section 2 presents the results and discussion. Finally, conclusions and future works are presented in section 3.

---

<sup>2</sup> IEA Global energy & CO<sub>2</sub> status report 2019 (available at: [www.iea.org/reports/global-energyco2-status-report-2019/emissions](http://www.iea.org/reports/global-energyco2-status-report-2019/emissions)) (Accessed 22 June 2020).

<sup>3</sup> PCC, in: C.B. Field, V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, L.L. White (Eds.), *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2014a.

<sup>4</sup> Arshian, S.Ozge, B.Gizem, U. Ilhan, O. Avik, S.,2020. Revisiting the role of renewable and non-renewable energy consumption on Turkey's ecological footprint: Evidence from Quantile ARDL approach. [Sustainable Cities and Society](#). 57, 102138.

## 2. Methodology

### 2.1. Base des données et analyse descriptives

In our study, the data are extracted from the World Bank indicators (CD-ROOM2019). These are Renewable Energy Consumption (REC), CO2 Emissions and Electricity Generation from Oil, Gas and Coal Sources (NCER) of Saudi Arabia observed from 1990 to 2019. .

The descriptive study of all our variables is summarized in Table 1.

Variables	Mean	Min	Max	Obs
Emission CO2	347064	171407.1	565191.2	30
CER	0.014894	0.009032	0.037985	30
NCER	75.97993	67.67312	86.99797	30

Source: estimate by the author using Eviews 9.

### 2.2. The ARDL econometric model

In this study, we use the ARDL cointegration approach (Auto- Regressive Distributed Lags) to examine the short- and long-term cointegration relationship between economic growth and political stability for each country. The ARDL cointegration procedure was introduced by Pesaran and Shin (1999) and extended by Pesaran et al.(2001). Compared with other cointegration methods (Engle Granger test, 1987; Johansen test, 1988; Johansen and Juselius test, 1990) the ARDL cointegration approach has advantages. This cointegration technique does not require the assumption that all variables come from the same order of integration. This approach can be applied even if the variables are I (0) or I (1). We choose this technique for two main reasons: -First, it is effective in executing short and long term relationships between different variables that do not have the same order of integration provided that these variables are stationary integration order level are I (0 ) or I (1). Second, the ARDL approach can remove problems associated with omitted and auto correlated variables. Third, it can be useful for a small application<sup>5</sup>. In order to study the relationship between economic growth and political stability, Solow's growth model is used as a theoretical framework. The model shows that national production (Y) is determined by three factors: capital (K), labor (L) and technical progress (A). The production function takes the following form:

$$Y=A f (K, L) \quad (1)$$

Equation (3) will be estimated in the following form:

$$CO2(t) =\alpha_0 + \beta_1 CER(t)+ \beta_{12} NCER(t) + \varepsilon (t) \quad (2)$$

L'équation du modèle ARDL s'écrit comme suit:

$$\Delta CO2_t = \beta_0 + \sum_{i=0}^n \beta_{1i} \Delta CO2_{t-i} + \sum_{i=0}^n \beta_{2i} \Delta CER_{t-i} + \beta_3 NCER_{t-1} + \varepsilon_t \quad (3)$$

Where,  $\Delta$  is the delay operator;  $\beta_0$  is the constant; mean short-term dynamics; while: are the long-term coefficients and  $\varepsilon$  is the error term of the white noise. After regression of Equation (3), the Wald test (F-statistic) was used to identify the existence of the long-run relationship between the different variables. The Wald test for multiple parameters can be carried out by imposing restrictions on the estimated long-run coefficients of GDP with the different variables of the model:

$$H_0: \beta_1 = \beta_2 = \beta_3 = \text{(no long run relationship)}$$

$$H_1: \beta_1 \neq \beta_2 \neq \beta_3 \text{ (a long run relationship exists)}$$

The model is verified under the assumptions H0 (no existence of the co-integration relationships), and H1 (existence of cointegration relationships).

### 3. Empirical results and discussion

We begin by examining the properties of the unit root by applying the Augmented Dickey-Fuller (ADF) and Phillips Perron (PP) unit root tests. These tests were carried out to verify the stationarity of our data series. The ADF and PP unit root test series in Table 2 reveal level stationarity for CER, i.e. I (0) at the 5% and 10% thresholds. The other two series (NCER and CO2) are stationary in first differences (I (1)) at the 5% and 10% thresholds. The ADF and PP unit root tests reveal that all series are I(1) and I(0). We therefore implement the cointegration test procedure. The first step consists of determining the order "p" of the VAR process to be retained. For this, we estimated various VAR processes for a maximum

<sup>5</sup> Pesaran M, Shin Y, Smith R. Bounds testing approaches to the analysis of level relationships. J Appl Econom. 2001;16:289e326.

order of delay “p” equal to 2. Considering the results of Table 3, the maximum number of lags which ensures serial non-autocorrelation and minimization of the information criteria is  $p = 2$  according to the Akaike information criterion (AIC) and according to the information criterion of Schwarz (SIC). Therefore, we look for ARDL models (p, q, r) such that the choice of delays serves to minimize the AIC criterion. According to Figure 1, the appropriate delays of the optimal ARDL model are: ARDL (4, 0, 0). The step following the determination of the optimal model (optimal delays) consists of testing cointegration. The cointegration method which follows the approach of Pesaran et al. (2001) in the optimal ARDL model is based on the following Wald test: The results of F-statistics in Table 4 confirm that there exist long-term cointegration relations. The result of table 5 implies the existence of long-term cointegration relationship between climate change, renewable and non-renewable energy. The CUSUM and CUSUMSQ tests are frequently indicated in graphic form Figs. 2 and 3 as below. The value of the statistic must then be verified under the null hypothesis that indicates the stability of the relationship curve in an interval (Bresson and Pirotte, 1995) fixed by two straight lines. In the case of a time series, the stability tests, also called structural change tests, examine the stability of the estimated coefficients of the equation while showing the presence of a structural change in the correlation. The CUSUM test is then adapted to test the hypothesis of stability of the long-run relations between climate change, renewable energy and non-renewable energy, the CUSUM and CUSUMQ test curves are within the 5% confidence interval.

Table 2: Level and difference unit root testing

Variables	PP		ADF	
	Level	In difference	Level	In difference
CER	-2.704 (0.0856**)		-3.174 (0.0324*)	
NCER	-1.622 (0.422)	-3.588 (0.012*)	-1.857 (0.345)	-3.587 (0.013*)
CO2	-8.257 (0.000*)		-2.722 (0.085**)	

Source: estimate by the author using Eviews 9.

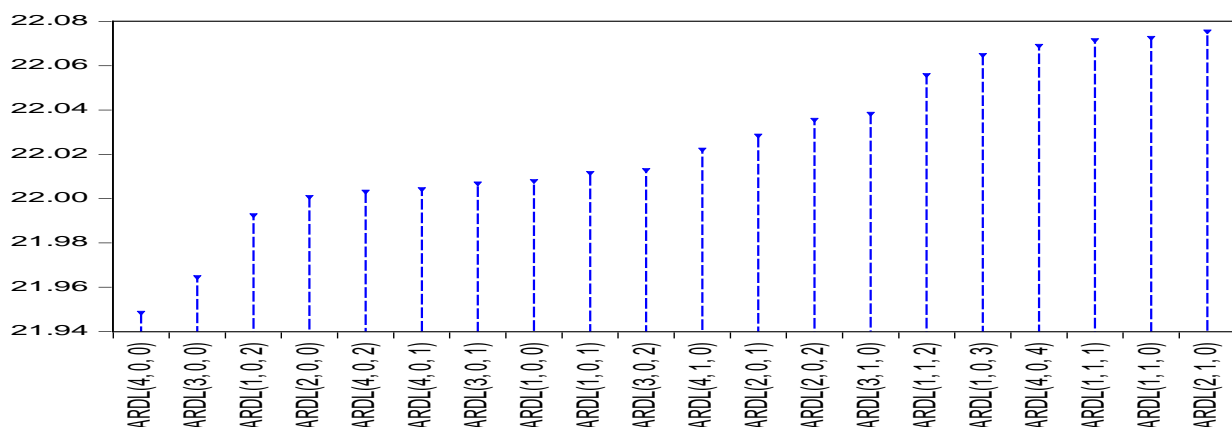
Table3: retard optimal

Lag	Log	AIC	SC	HQ
0	-28.32414	2.246233	2.342221	2.274775
1	36.08751	-2.228704*	-1.940741*	-2.143078*
2	37.761	-2.056388	-1.576449	-1.913677

Source: estimate by the author using Eviews 9.

Fig. 1. Akaike Information Criteria (AIC). \* The probabilities may be invalid for this equation specification.

Akaike Information Criteria (top 20 models)



Source: estimate by the author using Eviews 9.

Table 4. ARDL Bounds test. Null hypothesis (H0): No long-run relationships exist

Test statistic	Value	K
F-statistic	6.98163	2
Critical value		
Significance		
10%	I0 Bound	I1Bound
5%	2.63	3.35

2.5%	3.1	3.87
1%	3.55	4.38
	4.13	5

Source: estimate by the author using Eviews 9.

Table 5: Long term estimate

Variables	Coefficient
CER	-0.214583 (0.0762**)
NCER	-0.533823 (0.0346*)
Constant	70030.34 (0.1369)

Source: Author's estimate using Eviews 9.

Note: \*and \*\* denote significance at 5% and 10% level, respectively.

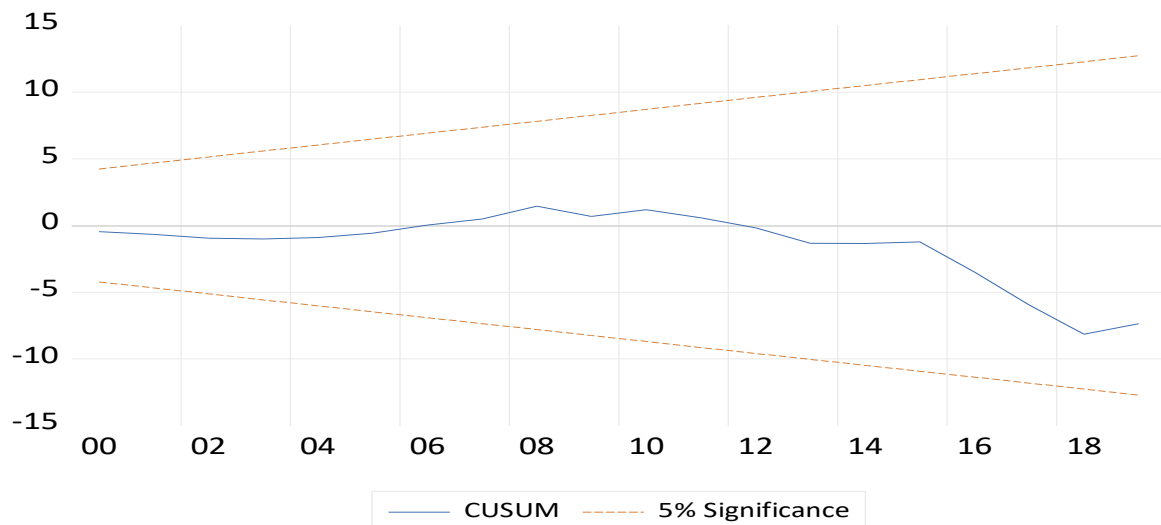


Fig.2 CUSUMS Test

Source: Estimate by the author using Eviews 9.

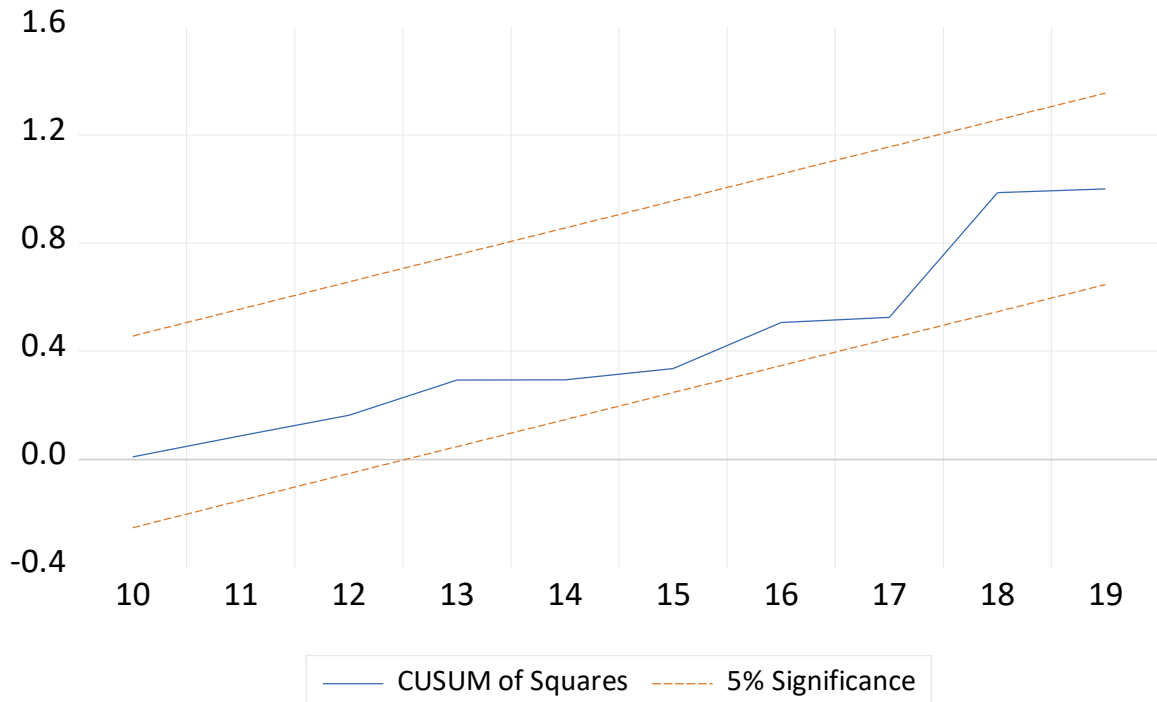


Fig.3 CUSUMSQ Test

Source: Estimate by the author using Eviews 9.

#### 4. Conclusions

The objective of this article is to study the impact of renewable and non-renewable energy on climate change in Arabia. The results prove that renewable and non-renewable energy negatively affect climate change in the long term. In the production process, energy consumption creates greenhouse gases and waste that harm the environment. Climate Change is approximated by the level of emissions (CO<sub>2</sub>), the average temperature for the country. Higher energy consumption will ultimately lead to higher carbon dioxide (CO<sub>2</sub>) emissions that violate its international commitments. Climate change is the largest and most severe of these impacts, driven primarily by the burning of fossil fuels, as well as significant greenhouse gas emissions from deforestation and the food system. While land is both the source and victim of climate change, it is also part of the solution. Sustainable land management practices can contribute to climate change mitigation strategies, ending and reversing greenhouse gas emissions from land-based sources. These practices can provide much-needed ecosystem services that help society adapt to the impacts of climate change.

#### References

1. Yalew S G et al 2020 Impacts of climate change on energy systems in global and regional scenarios *Nat. Energy* 5 794–802.
2. Cowan, W. N., Chang, T., Inglesi-Lotz, R., & Gupta, R. (2014). The nexus of electricity consumption, economic growth and CO<sub>2</sub> emissions in the BRICS countries. *Energy Policy*, 66, 359-368.
3. Cronin J, Anandarajah G and Dessens O 2018 Climate change impacts on the energy system: a review of trends and gaps *Clim. Change* 151 79–93.
4. Engle, R.F., Granger, C.W.J., 1987. Co-Integration and Error Correction: Representation, Estimation, and Testing. *Econometrica*. 55(2), 251-276.
5. Treut, H, Somerville, R, Cubasch, U, Ding Y, Mauritzen, C, Mokssit, A, Peterson, T, Prather, M (2007) Historical Overview of Climate Change. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S et al., (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
6. Rudolph, A., & Figge, L. (2017). Determinants of Ecological Footprints: What is the role of globalization? *Ecological Indicators*. 81 : 348-361.
7. Nathaniel, S. P. (2020) Mar. Ecological footprint, energy use, trade, and urbanization linkage in Indonesia. *GeoJournal*. 1-14.
8. Rahman, M. M. (2020). Environmental degradation: The role of electricity consumption, economic growth and globalisation. *Journal of environmental management*, 253, 109742.
9. Pesaran, M.H., Shin, Y., 1999. An autoregressive distributed lag modelling approach to cointegration analysis". In: Strom, S., Holly, A., Diamond, P. (Eds.). *Centennial Volume of Rangar Frisch*, Cambridge University Press, Cambridge.
10. Johansen, S., Juselius, K., 1990. Maximum Likelihood Estimation and Inference on Cointegration— with Applications to the Demand for Money. *Oxford Bulletin of Economics and Statistics*. 52(2). 169–210.
11. Johansen, S., 1988. Statistical Analysis of Cointegration Vectors. *Journal of Economic Dynamics and Control*. 2( 2–3), 231–254.
12. Engle, R.F., Granger, C.W.J., 1987. Co-Integration and Error Correction: Representation, Estimation, and Testing. *Econometrica*. 55(2), 251-276.
13. Pesaran, M.H., Shin, Y., Smith, R.J., 2001. Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics*. 16, 289-326.