Financial, Public and Regional Economics

Financial Inclusion and per Capita Income in Africa: Bayesian Var Estimates

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Abstract: Do higher per capita incomes translate into higher financial inclusion in Africa? Our application of the Bayesian VAR estimation approach to the World Bank Development Indicators datasets for 15 African countries provides affirmative evidence to this question. Using a Bayesian VAR approach for a panel of 15 countries in Africa over the period from 2005 to 2014, the findings show that per capital incomes, deposit interest rate and the internet has positive and significant impact on financial inclusion. That is, higher per capital incomes is associated with higher levels of financial inclusion in Africa. It is, however, interesting to note that financial inclusion is having a positive but insignificant impact on per capita income. Moreover, the internet is coming out to be a significant variable indicating that more attention is required to be paid to developing internet access in Africa for the advancement of financial inclusion. The findings of this study should be of help to African central banks' policymakers and commercial bankers as they advance innovative approaches to enhance the involvement of excluded poor people in formal finance.

Keywords: Financial inclusion; per capita income; Bayesian VAR

JEL Classification: G21; C23

1. Introduction

Do higher per capita incomes translate into higher financial inclusion? In other words, do higher incomes cause people to demand for and utilize higher quantum of formal financial services? Though Kelly & Rhyne (2013) suggest that they do, the connection has not been empirically established, especially in Africa. Our application of the Bayesian VAR estimation approach to the Worldbank Development datasets for 15 African countries provides affirmative evidence to these questions.

With the increasing clamor among multilateral agencies such as the International Monetary Fund, the World Bank and the African Development Bank, financial inclusion has become a widely recognized policy issue in the financial and economic arena, transcending into a vital social agenda. This stems from the

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importance of financial inclusion in achieving “sustainable growth, financial stability, and poverty alleviation” (Tatum, 2014, p. 1). Yet, all over the world the level of financial inclusion is as yet not commendable. According to Ardic, Heimann & Mylenko, (2011, p. 16):

“Fifty-six percent of adults in the world do not have access to formal financial services. The situation is even worse in the developing world with 64 percent of adults unbanked. Nevertheless, high-income countries also have to worry because approximately one in every five adults is unbanked. On the contrary to conventional wisdom, poor people indeed need and use financial services, albeit in small amounts and usually from informal sources as it is costly for formal providers to provide services for such small amounts. Anecdotal evidence suggests that informal financial services are at least 5-10 times more costly and also less reliable than formal ones. Hence, making formal and affordable financial services available for the unbanked would definitely have positive consequences on the lives of these people. Fortunately, the need for improving access to financial services and building inclusive financial systems are increasingly at the core of policymakers’ agendas”.

Most importantly, the financial system in Africa has grown tremendously both in volume and complexity in recent decades. Despite the significant improvements, “there are concerns that much needed banking services have not reached a vast segment of the population, especially the underprivileged sections of the society… The reasons may vary from country to country and hence the strategy could also vary but financial inclusion can truly lift the financial condition and standards of life of the poor and the disadvantaged” (Kumar, 2011, p. 2). As a result of this, countries all over Africa now embarks on inclusive growth drive. The importance of financial inclusion has become more obvious and moreover, “economic growth is no longer sufficient, rather a growth that trickles down all the way down to the bottom of the pyramid is now a necessity” (Tatum, 2014, p. 1).

In the literature, the significance of financial development for economic growth has been well-established (i.e. King & Levine, 1993; Levine, 2005; Demirgüç-Kunt, Beck, & Honohan, 2008). The importance of inclusive financial systems, as well, has entered the debate (Beck, Demirgüç-Kunt, & Peria, 2008) in more recent years. Studies such as Caskey, Duran, & Solo (2006) and Dupas & Robinson (2009) using household data have also shown that financial access in the form of savings, payments and credit can substantially and positively improve poor people’s lives. For firms, Schiffer & Weder (2001) and Beck et al., (2005, 2008) also found that financial access is often the major stumbling block to growth, especially in small and medium enterprises. The major gap in the literature, therefore, is to look at the significance of income to financial access.

It is therefore to ask if the level of income in Africa is appropriate for the needed financial inclusion. According to Kelly & Rhyne (2013, p. 10) "When the Global Findex asked people why they did not have a bank account, nearly two-thirds of the non-banked responded that they did not have enough money, and other responses dovetailed indirectly with not having enough money. A quarter of respondents said that formal services are too costly. Several other responses bear some relation to low incomes. If the service outlet is considered too far away, it may imply that the individual does not have enough money to get there. A lack of necessary documentation could also be related to low income".

With the objectives enumerated above, the current study is an attempt to understand the impact of per capita income on financial inclusion in Africa. A Bayesian VAR approach is employed for the country-wise panel data spanning over a period from 2005 to 2014, in the context of a panel of 15 countries in Africa. The findings corroborate significant impacts of per capita income on financial inclusion, signifying thereby how increase in incomes can be used to drive the needed financial inclusion in Africa. It is, however, interesting to note that financial inclusion is having a positive but insignificant impact on financial inclusion. Moreover, the internet is coming out to be a significant variable indicating that more attention is required to be paid to developing internet access in Africa for the advancement of financial inclusion. The findings of this study should be of help to African central banks' policymakers and commercial bankers as they advance innovative approaches to enhance the involvement of excluded poor people in formal finance.

The remainder of this article is organized as follows. Section 2 discusses the data, the Bayesian VAR, Im Pesaran & Shin panel unit root tests and the Pedroni Contegration test used. Section 3 discusses the results of the empirical analysis. Section 4 concludes with summary and key findings.

2. Data & Methodology

2.1. Data

Data for this analysis are collected from the World Development Indicators (WDI) on variables such as depositors with commercial banks (per 1,000 adults), per capital income, broad money, deposit interest rate, domestic credit provided by financial sector as a% of GDP, and internet users per 100 people. WDI was an appropriate source because it offers a large range of information on the variables. The data span is limited to 2005-2014 because of data availability. Depositors with commercial banks (per 1,000 adults) is our financial inclusion variable.

Table 1. Description of Variables

Variables	Description
Depositors with commercial banks (per 1,000 adults)	Depositors with commercial banks are the reported number of deposit account holders at commercial banks and other resident banks functioning as commercial banks that are resident nonfinancial corporations (public and private) and households. For many countries data cover the total number of deposit accounts due to lack of information on account holders. The major types of deposits are checking accounts, savings accounts, and time deposits.
GDP per capita (constant 2005 US$)	GDP per capita is gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in constant 2005 U.S. dollars.
Broad money (constant 2005 US$)	Broad money (IFS line 35L..ZK) is the sum of currency outside banks; demand deposits other than those of the central government; the time, savings, and foreign currency deposits of resident sectors other than the central government; bank and traveler's checks; and other securities such as certificates of deposit and commercial paper.
Deposit interest rate (%)	Deposit interest rate is the rate paid by commercial or similar banks for demand, time, or savings deposits. The terms and conditions attached to these rates differ by country, however, limiting their comparability.
Domestic credit provided by financial sector (% of GDP)	Domestic credit provided by the financial sector includes all credit to various sectors on a gross basis, with the exception of credit to the central government, which is net. The financial sector includes monetary authorities and deposit money banks, as well as other financial corporations where data are available (including corporations that do not accept transferable deposits but do incur such liabilities as time and savings deposits). Examples of other financial corporations are finance and leasing companies, money lenders, insurance corporations, pension funds, and foreign exchange companies.
Internet users (per 100 people)	Internet users are individuals who have used the Internet (from any location) in the last 12 months. Internet can be used via a computer, mobile phone, personal digital assistant, games machine, digital TV etc.

Source: World Development Indicators

2.2. Panel Unit Root Tests

This study carries out the Im Pesaran & Shin panel unit root tests on the dependent and independent variables so as establish their unit root properties. Im Pesaran and Shin Test (IPS) is given by

$$\Delta y_{it} = \rho_i y_{i,t-1} + \sum_{L=1}^{p_i} \phi_{iL} \Delta y_{i,t-L} + z'_{it}\gamma + u_{it} \quad (1)$$

Where $i = 1, \ldots, N$ and $t = 1, \ldots, T$

And the average of the *t*-statistics for p_1 from individual ADF regressions, $t_{iT_i}(p_i)$ is

$$\bar{t}_{NT} = \frac{1}{N} \sum_{i=1}^{N} t_{iT}(p_i \beta_i) \quad (2)$$

Which converges to the standard normal distribution as N and $T \rightarrow \infty$.

The major advantage of the IPS test is the assumption that the unit root can differ across the cross-sections in the model. As well, the alternative hypothesis assumes that at least one individual cross section is stationary. Moreover, the Im, Pesaran and Shin (2003) (IPS) test is used because the countries are heterogeneous. In line with Liew (2004), the Akaike Information Criterion (AIC) is used for the optimal lag selection.

2.3. Pedroni Residual Cointegration Test

The Pedroni (1999) Residual Cointegration Test is used to test for cointegration, since variables exhibiting unit roots in levels may have a linear combination in the long-run. The Engle-Granger based Pedroni (1999) cointegration is heterogeneous (Camarero & Tamarit, 2002), with the same deterministic trend assumptions as used in the IPS (2003) unit root test. The optimal lag selection is by the AIC (Liew, 2004).

Pedroni (1999) proposed a cointegration test that allows for heterogeneous intercepts and trend in coefficients across the cross-sections. Considering,

$$y_{it} = \alpha_i + \delta_i t + \beta_{1i} x_{1i,t} + \ldots + \beta_{li} x_{li,t} + \varepsilon_{i,t} \quad (3)$$

For t=1... T; i=1... N; l=1... L; where x and y are integrated of order one. α_i and δ_i are individual and trend effects. The test has the null hypothesis of no cointegration and the assumption that the residuals have unit root, with the standardized statistic asymptotically normally distributed of the form,

$\frac{\aleph_{N,T}-\mu\sqrt{N}}{\sqrt{v}} \rightarrow N(0,1)$, where μ and v are produced by the Pedroni via Monte Carlo simulations.

2.4. Bayesian VAR

In Bayesian statistics and econometrics, the *prior*, *likelihood*, and *posterior's* distributional properties are important. Anything uncertain is a random variable which is assigned a probability distribution. While the prior is based on knowledge of the parameters of interest, the likelihood is the information in the sample. Using Bayes' theorem, the combination of the prior distribution and the likelihood yields the posterior distribution.

If the parameters of interest are given by $\theta = (\beta, \sum)$, the data by *y*, the prior distribution by $\boldsymbol{\pi}(\theta)$ and the likelihood by $l(y|\theta)$, then the posterior distribution, $\boldsymbol{\pi}(\theta|y)$ is given by

$$\pi(\theta \mid y) = \frac{\pi(\theta) l(y \mid \theta)}{\int \pi(\theta) l(y \mid \theta) d\theta} \tag{4}$$

To relate this to the general Bayesian VAR framework, if the VAR(p) model is given by

$$y_t = \alpha_0 + \sum_{j=1}^{p} C_j y_{t-j} + \varepsilon_t \qquad t = 1, \ldots, T \tag{5}$$

Where y_t is an n x 1 vectors of n series and ε_t is an n x 1 vectors of errors.

For brevity, (2) may be rewritten as:

$$Y = BC + E \tag{6}$$

Or

$$y = (L_n \otimes B)\theta + e \tag{7}$$

Y and E are T x n matrices while $B = (b_1, \ldots, b_t)'$ is a T x (np + 1) matrix for $b_t = (1, y'_{t-1}, \ldots, y'_{t-q})$, L_m is the identity matrix of dimension n, θ = vec(C), and $e \sim N(0, \sum_E \otimes L_m)$.

The likelihood function, therefore, is

$$l(\theta, \Sigma_t) \propto |\Sigma_t \otimes L_T|^{-1/2} \exp\left\{-\frac{1}{2}(y-(L_n \otimes B)\theta)'(\Sigma_t \otimes L_T)^{-1}(y-(L_n \otimes B)\theta)\right\} \tag{8}$$

Assuming Σ_t is a multivariate normal prior for θ, then

$$\pi(\theta) \propto \left|V_0\right|^{-1/2} \exp\left\{-\frac{1}{2}(\theta-\theta_0)'V_0^{-1}(\theta-\theta_0)\right\} \tag{9}$$

Where V_0 is the prior covariance and θ_0 the prior mean.

Combining the prior with the likelihood function in (5), the posterior density becomes

$$\pi(\theta \mid y) = \exp\left\{-\frac{1}{2}.((V_0^{-1/2}(\theta-\theta_0))'V_0^{-1/2}(\theta-\theta_0) + \left\{(\Sigma_t^{-1/2} \otimes L_T)y - (\Sigma_t^{-1/2} \otimes B)\theta\right\}'\left\{(\Sigma_t^{-1/2} \otimes L_T)y - (\Sigma_t^{-1/2} \otimes B)\theta\right\}\right\} \tag{10}$$

(7) is a multivariate normal probability distribution function (pdf).

For simplicity, we do some definitions:

$$w = \begin{bmatrix} V_0^{-1/2}\theta_0 \\ \\ \\ \\ (\Sigma_t^{-1/2} \otimes L_T)y \end{bmatrix} \tag{11}$$

$$W = \begin{bmatrix} V_0^{-1/2}\theta_0 \\ \\ \\ \\ (\Sigma_t^{-1/2} \otimes B) \end{bmatrix} \tag{12}$$

Now, the exponent in (7) can be rewritten as

$$\pi(\theta \mid y) \propto \exp\left\{-\frac{1}{2}(w - W\theta)'(w - W\theta)\right\} \propto \exp\left\{-\frac{1}{2}(\theta-\bar{\theta})'W'W(\theta-\bar{\theta}) + (w - W\bar{\theta})'(w - W\bar{\theta})\right\} \tag{13}$$

The posterior mean, $\bar{\theta}$, is

$$\bar{\theta} = (W'W)^{-1}W'w = \left[V_0^{-1} + (\Sigma_t^{-1/2} \otimes B'B)\right]^{-1}\left[V_0^{-1}\theta_0 + (\Sigma_t^{-1/2} \otimes B)'y\right] \quad (14)$$

Since Σ_t is assumed known, the second part of (10) is not random about $\bar{\theta}$. The posterior may therefore be summarized as

$$\pi(\theta \mid y) \propto \exp\left\{-\frac{1}{2}(\theta - \bar{\theta})'W'W(\theta - \bar{\theta})\right\} \quad (15)$$

In other words,

$$\pi(\theta \mid y) = \exp\left\{-\frac{1}{2}(\theta - \bar{\theta})'\bar{V}^{-1}(\theta - \bar{\theta})\right\} \quad (16)$$

And the posterior covariance, $\bar{V}$ is

$$\bar{V} = \left[V_0^{-1} + (\Sigma_t^{-1/2} \otimes B'B)\right]^{-1} \quad (17)$$

2.5. Litterman or Minnesota Prior

The incorporation of the prior distribution of the parameters, in order to strengthen inferences about their true value, is proper for Bayesian analysis. While there are different priors popular in the BVAR literature (i.e. Litterman/Minnesota prior, Normal-Wishart prior, Sims-Zha normal-Wishart prior and Sims-Zha normal-flat), this study adopts the Litterman/Minnesota prior which is based on the assumption that Σ_t is known and therefore yields to simplifications in prior elicitation and calculation of the posterior.

Further, out of the three choices of an estimator of Σ_t (i.e. univariate AR, full VAR and diagonal VAR), this study adopts the univariate AR where $\hat{\Sigma}_\varepsilon$ has a diagonal matrix restriction, where $\hat{\sigma}_{ii}^2$ is (i, i) –th element of $\hat{\Sigma}_\varepsilon$, the estimate of the error variance of the *i*-th variable from a univariate AR regression.

The Litterman prior assumes the prior of θ

$$v \sim N(v_0, V_0) \quad (18)$$

$\theta_0 = 0$ and $V_0 \neq 0$.

Since the explanatory variables in any VAR equation consist of own lags of the dependent variable, the constant term, lags of the other dependent variables, and lastly any exogenous variables, the components of V_0 conforming to the exogenous variables are set to infinity. The remainder of V_0 becomes a diagonal matrix with elements v^l_{ij} for l = 1, …, p

$$v_{ij}^{l} = \left\{ \frac{\lambda_1}{l^{\lambda_3}} \right\}^2 \text{ for (i = j)}$$

$$v_{ij}^{l} = \left\{ \frac{\lambda_1 \lambda_2 \sigma_i}{l^{\lambda_3} \sigma_j} \right\}^2 \text{ for (i} \neq \text{j)} \tag{19}$$

Where σ_i^2 is the *i*-th diagonal element of Σ_ε. λ_1, λ_2 and λ_3 are the three scalars for overall tightness, relative cross-variable weight and the lag decay respectively.

The posterior for θ now takes the form

$$\theta \sim N(\bar{\theta}, \bar{V}) \tag{20}$$

Where

$$\bar{V} = \left[V_0^{-1} + (\hat{\Sigma}_\varepsilon^{-1/2} \otimes B'B) \right]^{-1} \tag{21}$$

And

$$\bar{\theta} = \bar{V} \left[V_0^{-1} \theta_0 + (\hat{\Sigma}_\varepsilon^{-1/2} \otimes B)' y \right] \tag{22}$$

3. Empirical Analysis

The descriptive statistics for depositors with commercial banks (per 1,000 adults) (FINC), GDP per capita (constant 2005 US$) (GDPC), broad money (MONEY), deposit interest rate (INTEREST), domestic credit provided by financial sector as a% of GDP (CREDIT), and internet users per 100 people (INTERNET) for the 15 countries are presented in Table 2. The standard deviation is a measure of the amount of variation of a set of data values. Among variables for the 15 countries, per capita income is the most volatile. Kurtosis is a measure of "peakedness" of a distribution. For GDPC, CREDIT, INTERNET and INTEREST series for the 15 countries, the Kurtosis statistics is more than 3, meaning that the distributions are leptokurtic relative to the normal. The Jarque-Bera test determines whether the series are normally distributed. The J-B statistic of all the series surpass the 5% critical value of 5.99, thus rejecting the null of normal distribution.

Table 2. Descriptive Stats

	FINC	GDPC	MONEY	CREDIT	INTEREST	INTERNET
Mean	340.5080	2446.836	27.12722	31.03451	5.566371	13.04333
Median	286.5703	1005.748	27.64236	21.57777	3.903333	8.032688
Maximum	940.7300	9494.280	30.53428	192.6601	18.40972	56.80000
Minimum	13.87084	211.2941	22.19383	-114.6937	1.750000	0.294034
Std. Dev.	256.1285	2447.303	2.048238	51.07377	3.469951	13.42446
Skewness	0.489082	1.175058	-0.519370	1.275751	1.514876	1.669177
Kurtosis	1.977365	3.428268	2.193872	6.021274	5.166079	5.094441
Jarque-Bera	11.18110	31.86104	9.652606	87.31362	77.44808	86.71635
Probability	0.003733	0.000000	0.008016	0.000000	0.000000	0.000000
Sum	45628.07	327876.1	3635.047	4158.624	745.8938	1747.806
Sum Sq. Dev.	8725044.	7.97E+08	557.9719	346934.5	1601.395	23968.74
Observations	134	134	134	134	134	134

Table 3 below highlights the results of the IPS panel unit root test. It can be observed that the variables are all non-stationary in levels; specifically, they all exhibit a unit root. This points to the possibility of long-run equilibrium among the variables because the variables, in the long-run, may have a linear combination. (Engle & Granger, 1987).

Table 3. IPS Panel unit root test

	I(0)	I(1)
FINC	3.864	-2.630*
GDPC	2.838	-2.696*
INTEREST	-0.418	-2.349*
MONEY	0.928	-10.001*
CREDIT	-0.613	-4.434*
INTERNET	2.819	-4.827*

*Notes: * denote significance at 1%. Optimal lags are chosen with the AIC.*

Table 4 presents the Pedroni Residual Cointegration Test results. Largely, the results show the absence of a long-run relationship between financial inclusion and per capita income in sub-Saharan Africa. Therefore, per capita income does not have a long-run relationship with financial inclusion. It demonstrates that, permanent changes in per capita income do not affect permanent changes in financial inclusion in the long-run.

Table 4. Pedroni Residual Cointegration Test

Null Hypothesis: No cointegration					
Use d.f. corrected Dickey-Fuller residual variances					
Newey-West automatic bandwidth selection and Bartlett kernel					
Alternative hypothesis: common AR coefs. (within-dimension)					
				Weighted	
		Statistic	Prob.	Statistic	Prob.
Panel v-Statistic		0.429865	0.3336	-0.141593	0.5563
Panel rho-Statistic		0.596781	0.7247	-0.038566	0.4846
Panel PP-Statistic		-0.580164	0.2809	-2.698408	0.0035
Panel ADF-Statistic		-0.515456	0.3031	-1.012549	0.1556
Alternative hypothesis: individual AR coefs. (between-dimension)					
		Statistic	Prob.		
Group rho-Statistic		1.774640	0.9620		
Group PP-Statistic		-3.602082	0.0002		
Group ADF-Statistic		-0.501898	0.3079		

The BVAR estimates in Table 5 shows that while GDPC, INTERNET and INTEREST has positive significant impact on FINC while only CREDIT has positive and significant impact on GDPC. MONEY has negative but insignificant impact on both GDPC and FINC. In other words, financial inclusion is better explained by per capita income, deposit interest rate and the internet. However, per capita income is not explained by any of the endogenous variables except CREDIT. This outcome indicates per capital income has not been large enough to boost financial inclusion in Africa.

Table 5. Bayesian VAR Estimates

Prior type: Litterman/Minnesota						
Initial residual covariance: Univariate AR						
Hyper-parameters: Mu: 0, L1: 0.1, L2: 0.99, L3: 1						
Standard errors in ( ) & t-statistics in [ ]						
	FINC	GDPC	MONEY	CREDIT	INTEREST	INTERNET
FINC(-1)	0.808090	0.486176	-5.89E-05	0.005828	0.002684	0.011019
	(0.04299)	(0.39170)	(7.9E-05)	(0.00858)	(0.00141)	(0.00191)
	[18.7959]	[1.24118]	[-0.74216]	[0.67932]	[1.90260]	[5.77865]
GDPC(-1)	0.010426	0.882216	-4.29E-06	-0.001221	-0.000338	-0.000229
	(0.00309)	(0.02823)	(5.7E-06)	(0.00062)	(0.00010)	(0.00014)
	[3.37152]	[31.2563]	[-0.74998]	[-1.97597]	[-3.32559]	[-1.66704]
MONEY(-1)	-2.511125	-19.77633	0.986677	0.062258	-0.265694	0.525722
	(3.39849)	(31.0126)	(0.00629)	(0.67934)	(0.11172)	(0.15092)
	[-0.73889]	[-0.63769]	[156.867]	[0.09164]	[-2.37822]	[3.48342]
CREDIT(-1)	0.015084	3.018802	-0.000257	0.899425	0.009914	0.020779
	(0.13018)	(1.18791)	(0.00024)	(0.02604)	(0.00428)	(0.00578)
	[0.11588]	[2.54128]	[-1.06602]	[34.5401]	[2.31668]	[3.59414]
INTEREST(-1)	3.495374	-8.162343	0.006140	0.079086	0.554782	0.048321
	(1.60424)	(14.6399)	(0.00297)	(0.32070)	(0.05288)	(0.07123)
	[2.17883]	[-0.55754]	[2.06784]	[0.24661]	[10.4920]	[0.67833]
INTERNET(-1)	3.154760	-9.056205	-0.001040	-0.032059	-0.034998	0.839148
	(0.79491)	(7.24732)	(0.00147)	(0.15877)	(0.02610)	(0.03531)
	[3.96872]	[-1.24959]	[-0.70747]	[-0.20193]	[-1.34076]	[23.7666]
C	84.93859	714.9876	0.529481	2.885662	9.737883	-13.93257
	(96.1510)	(877.424)	(0.17795)	(19.2200)	(3.16124)	(4.26979)
	[0.88339]	[0.81487]	[2.97538]	[0.15014]	[3.08040]	[-3.26306]

R-squared	0.937344	0.944723	0.997248	0.938741	0.655347	0.965919
Adj. R-squared	0.933958	0.941735	0.997099	0.935429	0.636717	0.964077
Sum sq. resids	483364.4	38103999	1.317014	18088.14	508.9887	768.1006
S.E. equation	65.98965	585.9004	0.108927	12.76543	2.141374	2.630556
F-statistic	276.7648	316.1785	6703.065	283.4951	35.17715	524.3304
Mean dependent	353.0546	2424.098	27.23733	32.55798	5.585330	14.04036
S.D. dependent	256.7819	2427.283	2.022328	50.23636	3.552794	13.87913

Standard errors in ( ) & t-statistics in [ ]. If the t-statistics is more than 2, the variable in question has a significant impact on the dependent variable.

Figure 1 reports the inverse roots of the characteristic AR polynomial (see Lütkepohl,1991) and shows that the estimated VAR is stable since all roots have modulus less than one and are in the unit circle. Stability of the VAR ensures that certain results, such as impulse response standard errors, are valid.

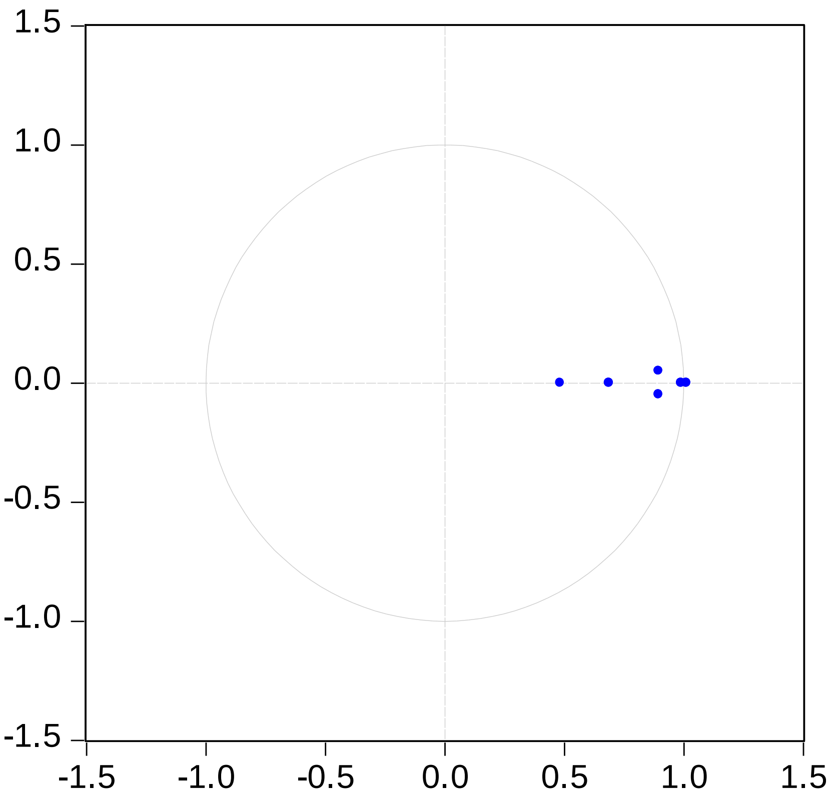

Figure 1. Inverse Roots of AR Characteristic Polynomial

Table 6 indicates lag order 1 as selected by the VAR lag order selection criteria. In other words, lag 1 is the most appropriate for the estimation.

Table 6. VAR Lag Order Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-2982.449	NA	1.13e+18	58.59705	58.75146	58.65957
1	-2120.901	1604.845	1.06e+11*	42.40983*	43.49070*	42.84751*
2	-2085.096	62.48356*	1.07e+11	42.41365	44.42098	43.22648
* indicates lag order selected by the criterion						
LR: sequential modified LR test statistic (each test at 5% level)						
FPE: Final prediction error						
AIC: Akaike information criterion						
SC: Schwarz information criterion						
HQ: Hannan-Quinn information criterion						

Since a shock to the i-th variable not only affects the i-th variable but also all of the other endogenous variables via the dynamic structure of the VAR, an impulse response function can be used to trace the effect of a one-time shock to one of the innovations on current and future values of the endogenous variables. Fig. 2a shows the impulse response functions of financial inclusion to per capita income and the other endogenous variables. While a unit shock to real per capita income, interest and internet produces, to a great extent, a positive effect on financial inclusion, the response of financial inclusion to money supply is largely insignificant. Per capita income has positive significant effects on financial inclusion from the results of the IRFs.

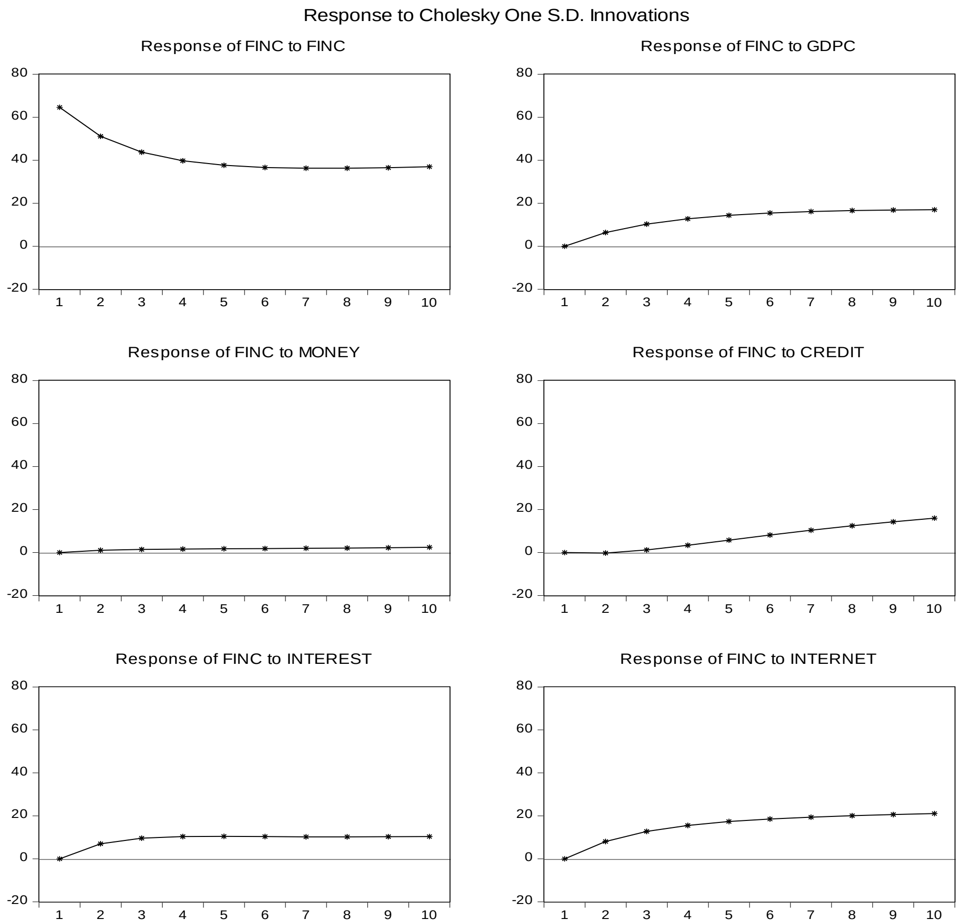

Figure 2a. Impulse Response Functions for FINC

Figure 2b shows the impulse response functions of per capita income to financial inclusion and the other endogenous variables. A unit shock to financial inclusion, and the other endogenous variables produces insignificant effects on financial inclusion. Financial inclusion has insignificant effects on per capita income from the results of the IRFs.

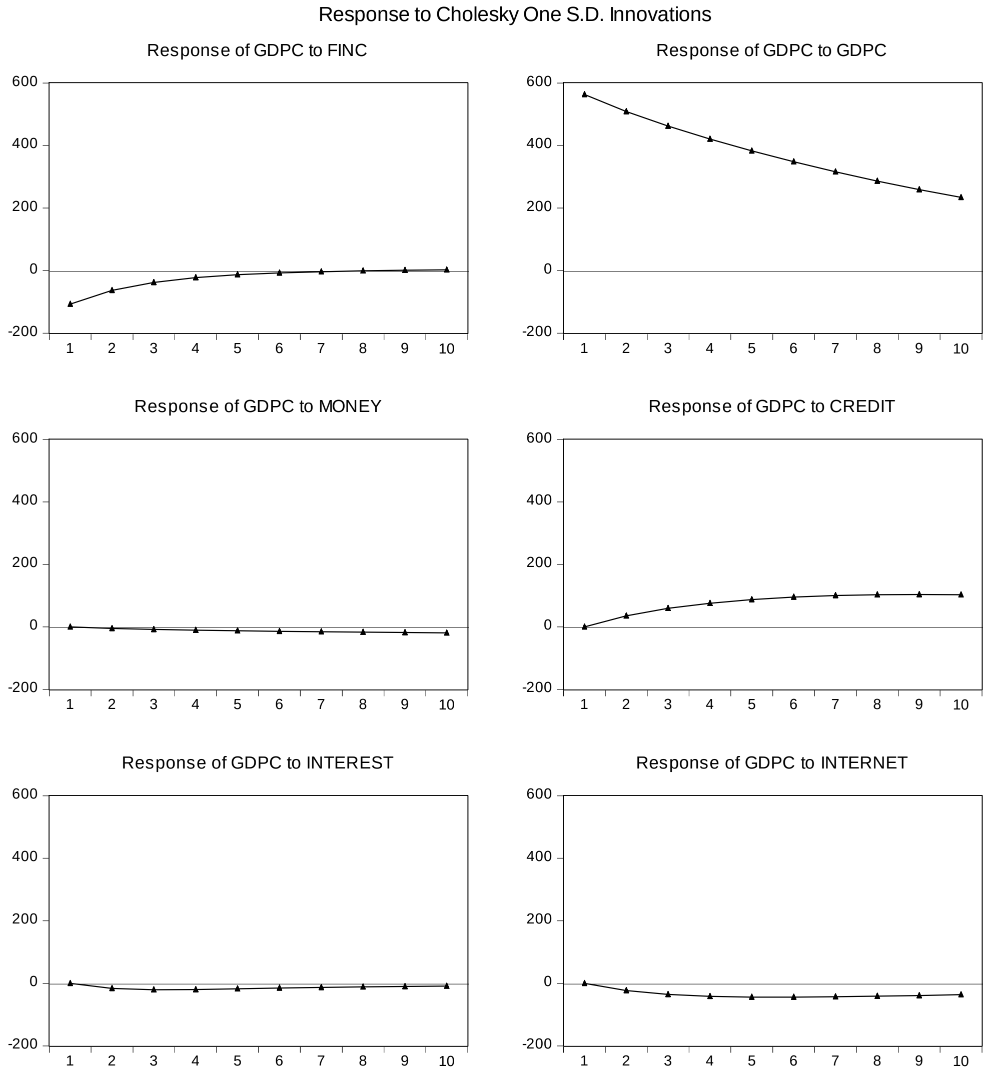

Figure 2b. Impulse Response Functions for GDPC

Variance decomposition can be used to separate the variation in an endogenous variable into the component shocks to the VAR. in other words, the variance decomposition offers information about the relative importance of each random innovation in influencing the variables in the VAR. In fig. 4, the forecast error variance of financial inclusion are better explained per capita income and internet. For per capital income, the rates of increase are very minimal. However, per capita income is not explained better by any of the endogenous variables except itself. This outcome indicates per capital income has not large enough to in boost financial inclusion in Africa.

Table 7. Variance Decomposition

Variance Decomposition of FINC:							
Period	S.E.	FINC	GDPC	MONEY	CREDIT	INTEREST	INTERNET
1	64.55180	100.0000	0.000000	0.000000	0.000000	0.000000	0.000000
2	83.26073	97.75622	0.581994	0.014926	0.001187	0.707970	0.937706
3	95.96174	94.37402	1.574800	0.033415	0.016241	1.534454	2.467067
4	106.3653	90.78334	2.707195	0.050037	0.113742	2.198866	4.146824
5	115.6775	87.34251	3.820570	0.064242	0.344197	2.674943	5.753537
6	124.4133	84.16836	4.833201	0.076750	0.723654	3.003496	7.194544
7	132.8273	81.28623	5.709202	0.088370	1.242044	3.229559	8.444593
8	141.0555	78.68837	6.438821	0.099727	1.875175	3.387730	9.510173
9	149.1738	76.35544	7.026650	0.111247	2.593867	3.501837	10.41096
10	157.2258	74.26454	7.484619	0.123205	3.369483	3.587596	11.17056
Variance Decomposition of GDPC:							
Period	S.E.	FINC	GDPC	MONEY	CREDIT	INTEREST	INTERNET
1	573.1341	3.512876	96.48712	0.000000	0.000000	0.000000	0.000000
2	770.1136	2.623718	97.02790	0.004163	0.209440	0.044454	0.090323
3	901.6868	2.091129	97.00946	0.011054	0.584757	0.083706	0.219893
4	999.1215	1.755082	96.71217	0.019746	1.054298	0.107562	0.351144
5	1074.662	1.532589	96.27213	0.030083	1.574878	0.120029	0.470288
6	1134.692	1.379064	95.76089	0.042131	2.118720	0.125839	0.573358
7	1183.098	1.269458	95.21921	0.055981	2.666905	0.128155	0.660287
8	1222.487	1.189040	94.67197	0.071691	3.206074	0.128788	0.732439
9	1254.728	1.128757	94.13498	0.089266	3.726696	0.128703	0.791596
10	1281.219	1.082824	93.61851	0.108662	4.222068	0.128392	0.839547
Cholesky Ordering: FINC GDPC MONEY CREDIT INTEREST INTERNET							

The results of the BVAR estimates, the impulse response function and the variance decomposition have all shown that per capita income, the internet and the deposit interest rate are the major determinants of financial inclusion in sub-Saharan Africa. Our findings are consistent with Park & Mercado (2015) which found that per capita income is the main determinant for financial inclusion and Kumar (2011) which found that income has a positive and significant impact on the level of financial inclusion. Honohan (2008) also found that there is a correlation between the two, though not able to establish if it is causal.

The finding that financial inclusion has positive but insignificant impact on per capita income in Africa is very interesting for policy implications. While a strong financial system is "a pillar of economic growth, development and progress of an economy" and "a financial system, which is inherently strong, functionally diverse and displays efficiency and flexibility, is critical to our national objectives of creating a market-driven, productive and competitive economy" (Kumar, 2012, p. 1), the financial system in Africa is not mature enough to support higher quanta of investment and growth with its puny financial depth and coverage. In this contemporary era of attaining economic clout and self-reliance, it is, therefore, imperative for every sub-Saharan African regime to create friendly conditions for the delivery of banking services at affordable costs to its vast sections of disadvantaged low-income groups. For these countries, increasing per capita incomes will eliminate many of the arguments supporting low financial inclusion: people with high incomes are likely to save more, be bank-literate, and get more securities (Hariharan & Marktanner, 2013). Accordingly, the financial system is less likely to fail (Ardic, Heimann & Mylenko, 2011).

CREDIT has positive but insignificant impact on financial inclusion. On a more distinct note, both the number of micro, small and medium enterprises in Africa and the level of credit extended to these enterprises are abysmally low, as a result of weak asset base and poor credit profile information and therefore may not make much impact in creating inclusive financial systems in the continent.

As well, the significant impacts of INTERNET have weighty policy implications for financial inclusion in Africa. While it can be an arduous task, in terms of the investment and cost effectiveness, to cover all the millions of villages in the African continent with brick and mortar branches of financial institutions, with high usage of the internet in Africa, financial inclusion can be broadened. Via the mobile and the ATM, the internet can drastically reduce the cost of transactions. Internet can increase the potentials of credit delivery in remote areas of the continent. It can make it possible to provide home banking services where the accounts are operated by illiterate customers using mobiles. According to Hariharan & Marktanner (2013, p.): "For example, in many developing countries, cell phone providers have successfully entered the market for the safe transfer of funds. Cell phone users use their phones to transfer money to other family members or to pay bills to businesses. Cell phone companies have therefore excellent access to data that can be used to build a credit profile of cell phone users. This credit profile could serve as a substitute for the absence of collateral and reduce high transaction costs of gathering information about borrowers... It seems accordingly plausible to assume that a market would evolve in which cell phone companies either use these credit profiles as an input factor for banks willing to expand their credit business, or even enter the market for credit themselves. To which extent this will occur, however, depends substantially on the regulatory quality of the country…"

In fact, free access to the internet as a public good and service can be the sine qua non to an open and efficient financial system in Africa. It is vital that the availability of banking and payment services on the internet to the entire African population without discrimination becomes the prime objective of public policies. In other words, the internet should be harnessed as a major financial inclusion enabler in Africa.

As well, deposit interest rates have positive and significant impacts on financial inclusion. If the deposit interest rates are high, it is likely to significantly induce both existing and potential depositors. African central banks can therefore use interest rates as a more potent device for enhancing financial inclusion in Africa. Considering that the rewards for saving are influenced by interest rates, higher financial access brings a bigger share of economic activity under the control of interest rates, making them a more powerful tool for policymakers.

4. Conclusion

Do higher per capita incomes translate into higher financial inclusion in Africa? Our application of the Bayesian VAR estimation approach to the Worldbank Development Indicators datasets for 15 African countries provides affirmative evidence to this question. Using a Bayesian VAR approach for a panel of 15 countries in Africa over the period from 2005 to 2014, the findings show that per capital incomes, deposit interest rate and the internet has positive and significant impact on financial inclusion. That is, higher per capital incomes is associated with higher levels of financial inclusion in Africa. It is, however, interesting to note that financial inclusion is having a positive but insignificant impact on per capita income. Moreover, the internet is coming out to be a significant variable indicating that more attention is required to be paid to developing internet access in Africa for the advancement of financial inclusion. The results of this study have important policy implications for future policy design in African countries given financial innovations in the continent such as mobile money. The findings of this study should be of help to African central banks' policymakers and commercial bankers as they advance innovative approaches to enhance the involvement of excluded poor people in formal finance.

There are of course limitations to the analysis undertaken in this study. Using proxies such as Depositors with commercial banks per 1,000 adults as a measure of financial inclusion may not be adequate. It would therefore be worthwhile to examine other alternative measures which could enhance access to formal finance for excluded individuals, such as the nature and frequency of transactions that take place in these accounts. As well, what is true for the region may not necessarily be true for a specific country. A noble illustration of this is the evolution of mobile money in countries such as Nigeria, Kenya and South Africa. Further research may be necessary using country case studies to understand specific types of financial innovation proxies.

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APPENDIX: LIST OF THE 15 AFRICAN COUNTRIES IN THE SAMPLE

Algeria;

Angola;

Botswana;

Ghana;

Kenya;

Libya;

Malawi;

Mali;

Morocco;

Namibia;

Nigeria;

Niger;

South Africa;

Senegals;

Cameroon.

Europe 2020 Strategy vs Global Environment Protection's Challenge

Romeo-Victor Ionescu[1], Luminita-Maria Filip[2]

Abstract: The paper deals with the analysis of the latest events related to the environment protection and clean energy. This analysis is built on two levels. The first one is the analysis of the Europe 2020 Strategy regarding the environment and energy across the EU and points out the great disparities between the Member States. The second level is focus on the environment and energy consumption in Romania. It is followed by forecasting procedures related to the greenhouse gas emissions, the renewable energy in gross final energy consumption, the primary energy consumption and the final energy consumption. The main conclusion of the paper is that EU has to face to great challenges in this domain and the Strategy's goals achieving in 2020 is not sure. On the other hand, Romania has good performance for two from the four above specific indicators. The analysis is based on long term statistical data, pertinent diagrams and is supported by IBM-SPSS software.

Keywords: Environment protection; clean energy; renewable energy; greenhouse gas emission; energy consumption

JEL Classification: Q01; Q2; Q4; Q5; R11

1. Introduction

There is no doubt that the environment protection becomes vital for the future of the humanity. The national decision makers understood that the environment protection' problems don't stop at their national borders. As a result, the global approach is the unique viable solution for a realistic future on the Earth.

Many conferences and bi and multilateral meetings tried to put into an all accepted legal framework the solutions of the environment protection.

The last one covered the 21st annual session of the Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change

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(UNFCCC) and the 11th session of the Conference of the Parties (CMP) to the Kyoto Protocol (xxx, 2015).

According to Article 2 of the conference in Paris Agreement, the decision makers established to hold the increase in the global average temperature to well below 2 °C above pre-industrial levels (United Nations, 2015).

Moreover, during the Conference in Paris, the participants presented national plans able to reduce the pollutant emissions. The states agreed to present their individual contributions every five years and to operate under perfect transparency in achieving their environment protection targets.

On the other hand, the developed countries (including EU Member States) will finance the developing countries in order to protect the environment and to face the challenges related to the climate changes.

According to the above actions, EU defined Europe 2020 Strategy, which covers specific goals, including the environment protection. This document defined four environment headline indicators: greenhouse gas emissions, share of renewable energy in gross final energy consumption, primary energy consumption and final energy consumption (European Commission, 2010).

Unfortunately, the President of USA announced his country's withdrawal from the Paris Agreement regarding climate protection on June 2017. USA is the second world polluter after China. As a result, the above announce is very important for the world future environment protection even that China and Russia decided to respect the Treaty. Only two countries (Nicaragua and Syria) didn't sign this agreement till now.

The other countries of the world support the treaty. This is why, the next world conference on climate will be held in Bonn on November 2017.

In this context, EU has to play an important global role and the Europe 2020 Strategy becomes more and more important.

2. Literature Overview

Environmental pollution is considered as one of the vital present and future challenge for humanity. As a result, the interdisciplinary approach becomes essentially. From this point of view, is interesting to point out the key principles of pollution science and the impact of the pollution on natural element cycles. Pollution has global and local impacts and affects all elements which support life on the planet. The connection between pollution and health is inevitable (Rieuwerts, 2015).

The connection pollution-health represents the main element of a research which describes the measures to be taken to control industrial wastes. The different types of wastes are quantified and analysed on different elements: air, soil and water. Moreover, the analysis covers photochemical air pollution, marine pollution, thermal pollution, noise pollution, and radioactive pollution and their effects on human health. On the other hand, this book offers solutions for managing various types of wastes (Ahluwalia, 2014).

Other research is focused on the evolution of the EU environmental policy during 1970-2015. This analysis is followed by a review of main actors in EU environmental politics. Moreover, the environmental policy and its ecological impacts are quantified within and outside the EU and take into consideration the possibility of EU enlargement (Selin & VanDeveer, 2015).

An interesting point of view is an official one from UK, which considers that EU membership had been positive for the UK environment. Moreover, the environment was not a case for criticisms and Brexit. A distinct part of this approach is that related to the environmental costs and the financial contribution of each Member State. On the other hand, there are significant benefits to solving some environmental problems multilaterally (House of Commons, 2016).

An optimistic approach on EU environmental policies considers that they are the world's most stringent sets. The authors of this approach analysed in their book the interdependence between environment protection trend in the EU and at the global level. Moreover, the same authors focus on the EU as main actor in global environmental governance, especially in relation to climate change. (Delreux & Happaerts, 2016)

Last but not least a recent research focuses on Baltic Sea Region and applies the ecosystem approach to management in order to quantify the impact of different official action plans, directives and other institutional documents. The authors take into consideration HELCOM's Baltic Sea Action Plan, the EU Water Framework Directive, the EU Marine Strategy Framework Directive and the EU Maritime Spatial Planning Directive. A very interesting idea is that Russia is affected in its independence as long as it recognises and implements the EU legislation on Baltic Sea Region. (Söderström & Kern, 2017)

3. Europe 2020 Strategy Goals' Analysis

Europe 2020 Strategy covers five essential goals. One of them is climate change & energy. It is divided into four targets.

First is the level of the greenhouse gas emissions which is quantified as index related to its value of 100% in 1990. The EU target under this indicator is a decrease of 20% of these emissions in 2020 compared to 1990. The trend of the indicator is presented in Figure 1.

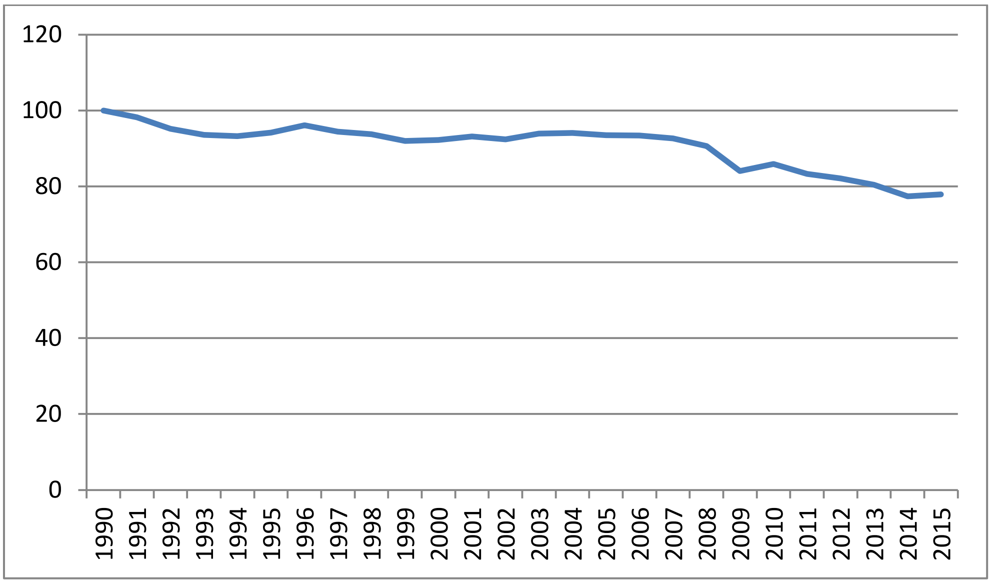

Figure 1. Greenhouse gas emissions (1990=100)

Source: Personal contribution

According to Figure 1, the EU 2020 Strategy's target was achieved in 2014 (European Environment Agency, 2017).

On the other hand, there are great disparities related this indicator between Member States. The gap between the best (Lithuania) and the worst (Cyprus) performances is 1: 3.44.

According to the latest official data, half of the Member States are not still able to achieve the greenhouse gas emissions standard from Europe 2020 Strategy. But the performances in this domain can cover an economic contraction, especially in industry, which is not a good thing.

Unfortunately, UK has good performance in decreasing greenhouse gas emissions, but it is during its exit from EU procedure.

The second specific target is the share of renewable energy in gross final energy consumption which faces to a very ambitious goal for 2020: 20% from whole energy consumption.

EU succeeded to increase permanently the share of renewable energy in total consumption during 2004-2015 (see Figure 2).

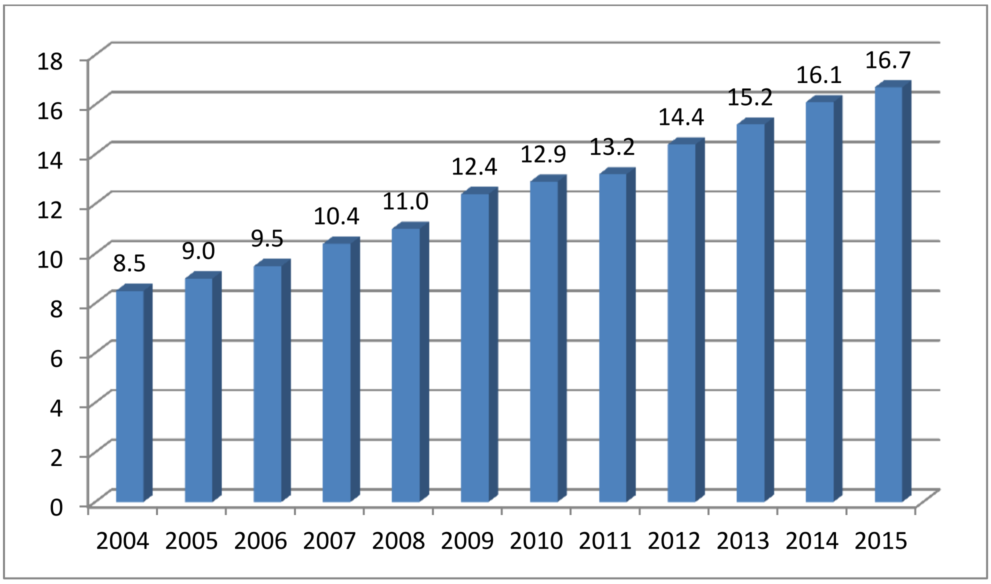

Figure 2. Share of renewable energy in gross final energy consumption

Source: Personal contribution

EU was not able to achieve the goal regarding the share of renewable energy yet (European Environment Agency, 2017b).

There are some contradictions related to this indicator between Member States. Some of them (Denmark, Estonia, Croatia, Latvia, Lithuania, Austria, Portugal, Romania, Slovenia, Finland and Sweden) achieved the target of renewable energy or more than it.

On the other hand, 15 Member States adopted lower national goals than the EU average. By opposite, Denmark, Estonia, France, Latvia, Lithuania, Austria, Portugal, Romania, Slovenia, Finland and Sweden established higher goals than the EU average. As a result, the gap between the worst (Luxembourg, Malta) and the best (Sweden) situations regarding renewable energy is huge 1: 10.78.

EU established a target of 1483 million tonnes of oil equivalent to the primary energy consumption in 2020. This target is far away of being achieved yet (see Figure 3).

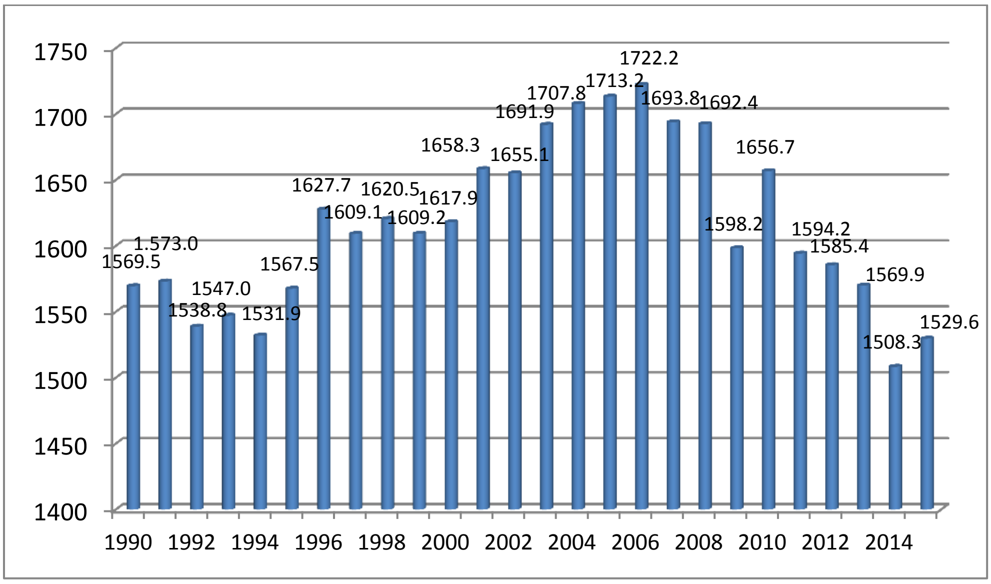

Figure 3. Primary energy consumption (mill. tonnes of oil equivalent-TOE)

Source: Personal contribution

The primary energy consumption levels followed the business cycle. It decreased during 2007-2009 as a result of the economic crisis. The economic recovery in the EU economy caused an increase of the primary energy consumption level in 2010, followed by continuous decreases until 2015 (Eurostat, 2017).

There are national targets regarding the primary energy consumption. Some Member States, as Denmark, Estonia, Greece, Spain, Croatia, Italy, Latvia, Cyprus, Lithuania, Luxembourg, Hungary, Austria, Poland, Portugal, Romania, Slovenia, Slovakia and Finland) succeeded in achieving the national targets in 2015. The greatest economies, as France, Germany and UK were not able to do the same thing. The best situation is in Romania, which decreased its primary energy consumption at 31.3 TOE in 2015 compared to its national target of 43 TOE in 2020. The worst situation is in Germany, which faced to a consumption of 292.9 TOE in 2015 compared to its target of 276.6 TOE in 2020.

The last indicator of the climate change & energy from the Europe 2020 Strategy is the final energy consumption, which has targeted at 1086 TOE in 2020. EU succeeded in achieving this target in 2014. Even that the final energy consumption grew again in 2015, it didn't excess to the target (see Figure 4).

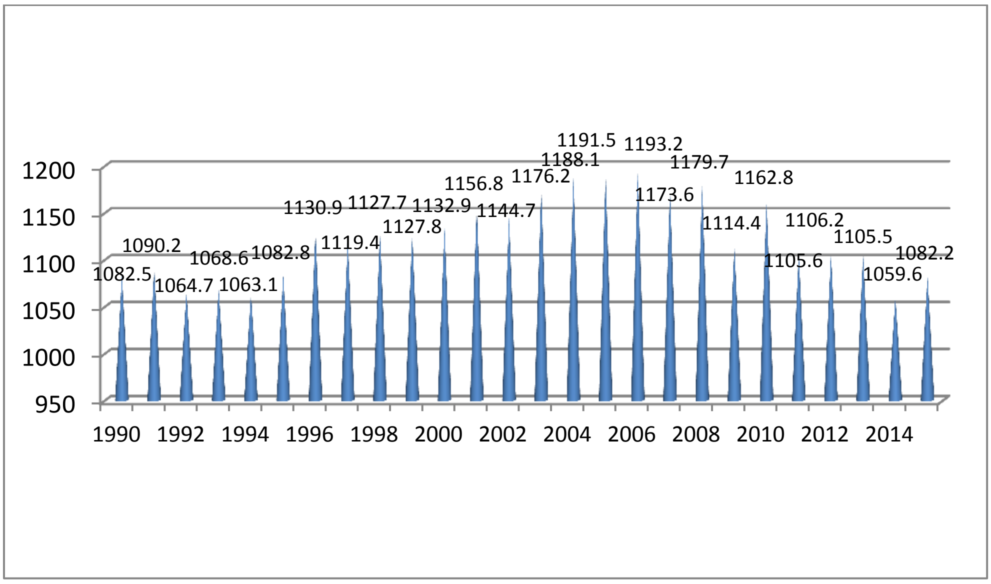

Figure 4. Final energy consumption (mill. tonnes of oil equivalent-TOE)

Source: Personal contribution

According to Figure 4, the evolution of the final energy consumption across the EU was fluctuant during 1990-2015 (Eurostat, 2017b).

In the same manner as for the primary energy consumption, the Member States established national targets for final energy consumption until 2020. Czech Republic, Denmark, Estonia, Ireland, Greece, Croatia, Italy, Cyprus, Latvia, Luxembourg, Netherlands, Poland, Portugal, Romania, Slovenia and Finland succeeded to achieve these targets in 2015. The best performance had Romania and the worst France.

In order to see the progresses realised by the EU in the climate change & energy domains a quadrilateral diagram become useful (see Figure 5).

The red line represents the targets of the climate change & energy chapter according to the Europe 2020 Strategy. The blue lines represent the situation in 2010, when the Strategy was adopted and the black lines represent the progresses made during 2010-2015.

According to the above assumptions, there are some difficulties related to the renewable energy and the primary energy consumption.

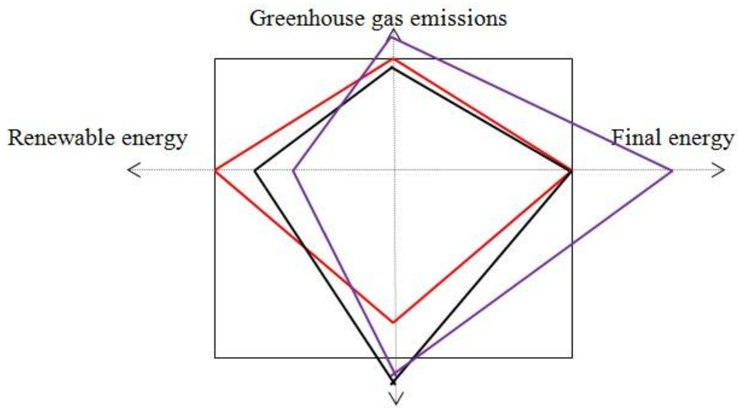

Figure 5. Climate change & energy diagrams

Source: Personal contribution

4. Climate Changes & Energy Challenges for Romania

As member of the EU, Romania applies the same strategy regarding the climate changes & energy. As a result, the greenhouse gas emissions had fluctuant evolution during 1990-2015 (see Figure 6).

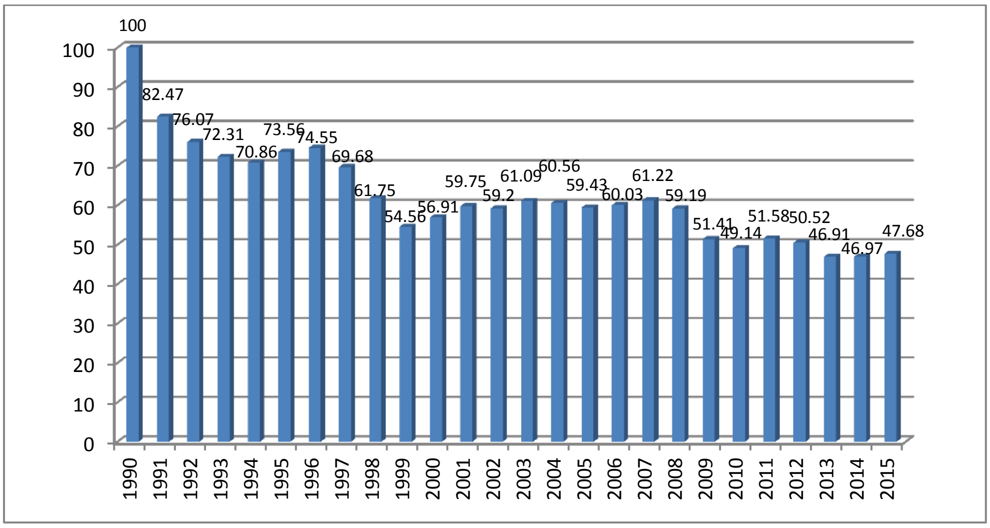

Figure 6. Greenhouse gas emissions in Romania (1990=100)

Source: Personal contribution

It was no problem for Romania to respect the Europe 2020 Strategy's goal for these emissions. Basically, the goal was achieved in 1992. On the other hand, the economic recession and the industry restructuration support a decrease of the greenhouse gas emissions in Romania.

The forecast of this indicator on medium term points out a positive evolution as in Figure 7. The annual values of the emissions represent dependent variables, while time is the independent variable. The forecasting procedure respects Expert Modeler conditions.

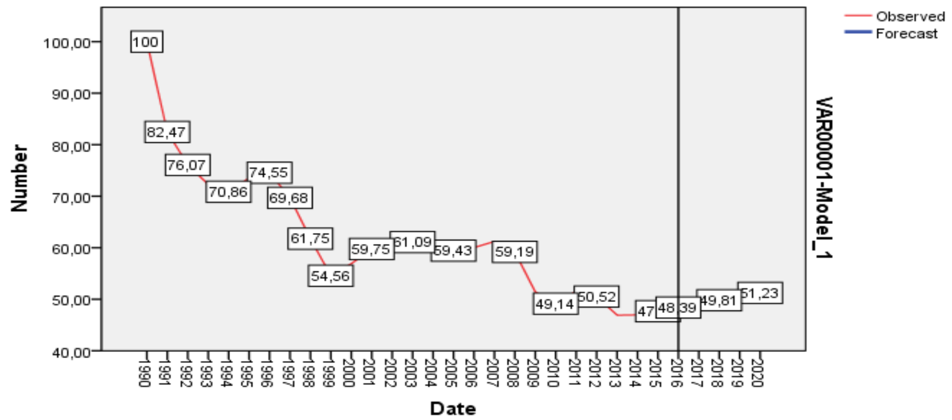

Figure 7. Greenhouse gas emissions' forecast in Romania

Source: Personal contribution using IBM-SPSS software

The forecast from Figure 7 is based on statistical data which cover 21 years. The result of such forecasting is better. Even that the emissions will increase during 2016-2020 due to the industrial recovery, the Strategy's target will be respected.

Romania establisher a higher standard than the EU regarding the share of renewable energy in gross final energy consumption: 24%. This target was achieved at the beginning of 2014 (see Figure 8).

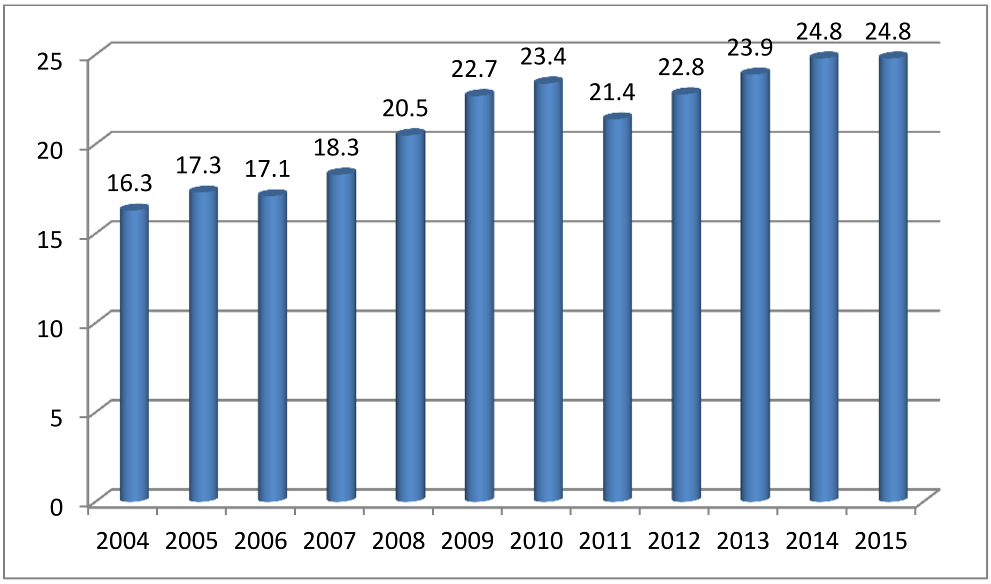

Figure 8. Share of renewable energy in gross final energy consumption in Romania (%)

Source: Personal contribution

The above diagram points out that Romania was able to achieve the specific EU goal in 2008. The forecast on average term leads to positive results (see Figure 9).

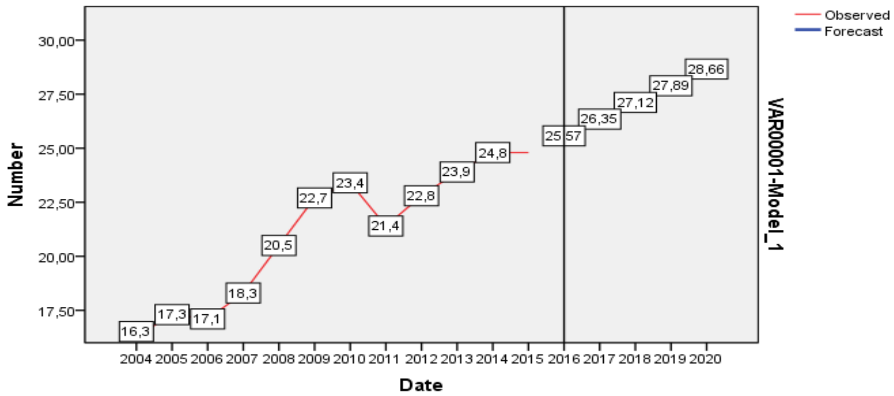

Figure 9. Renewable energy's forecast in Romania

Source: Personal contribution using IBM-SPSS software

According to Figure 9, Romania will continue to improve the share of renewable energy in gross final energy consumption until 2020. Even that the increase is not spectacular, Romania will fight for the first rank regarding this indicator across the EU.

On the other hand, Romania was able to decrease the primary energy consumption in order to achieve its national goal of 43 MOE since 1998 (see Figure 10).

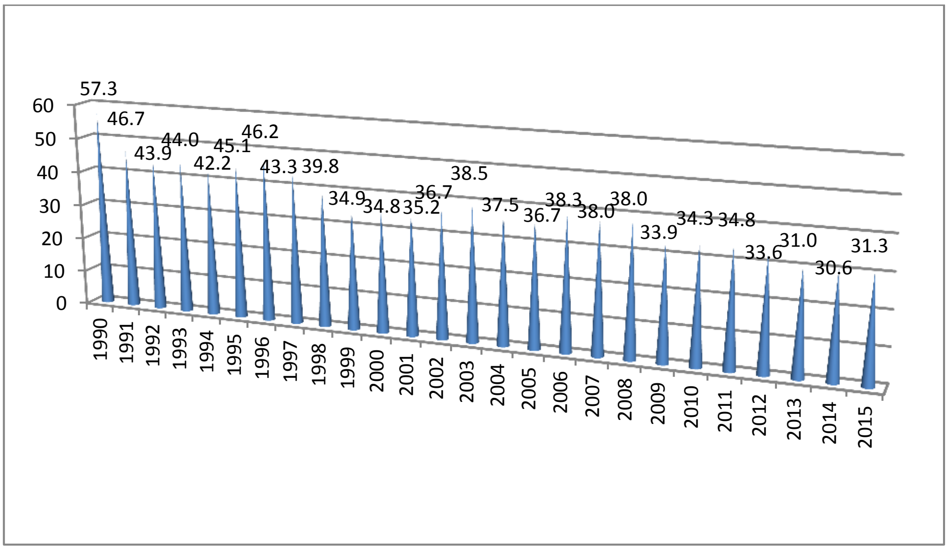

Figure 10. Primary energy consumption in Romania (TOE)

Source: Personal contribution

Under the same conditions, the forecast values of this indicator will decrease during 2016-2020 (see Figure 11).

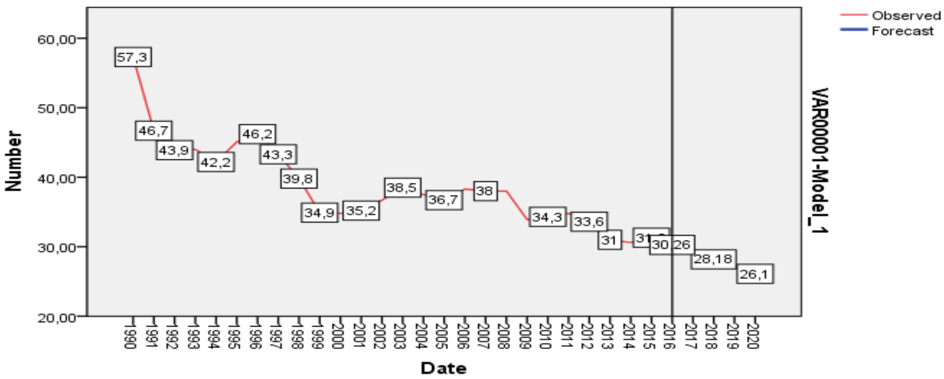

Figure 11. Primary energy consumption's forecast in Romania

Source: Personal contribution using IBM-SPSS software

The last indicator took into consideration is final energy consumption. Romania established a national target of 30.3 TOE, which was achieved in 1992. But the final energy consumption has to be correlated to the economic development. A contraction of the economy leads to a decrease in final energy consumption with negative impact on the socio-economic development (see Figure 12).

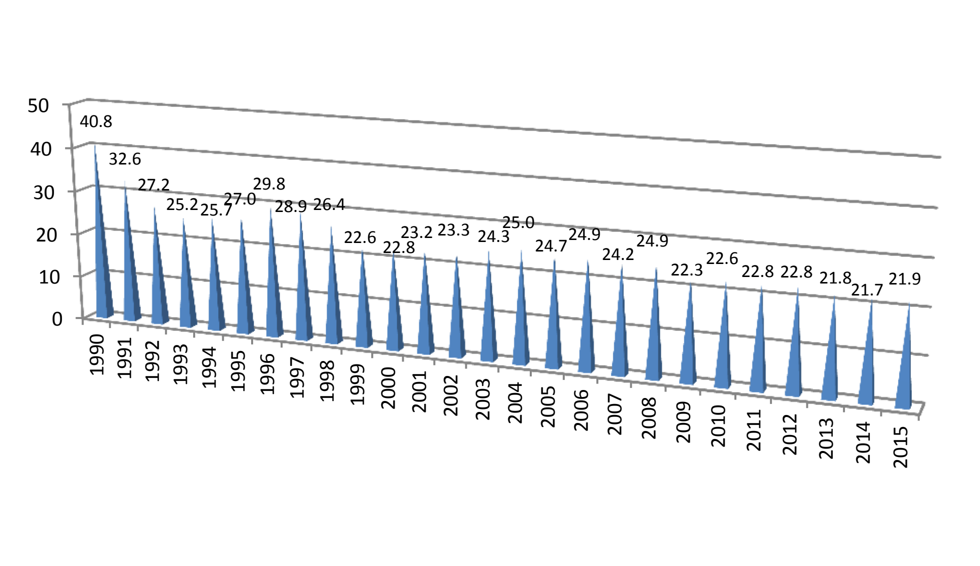

Figure 12. Final energy consumption in Romania (TOE)

Source: Personal contribution

During the last decade the final energy consumption in Romania achieved an average level of 22-23 TOE.

The trend of this indicator until 2020 is presented in Figure 13. Even in 2020, the final energy consumption will be below the national target.

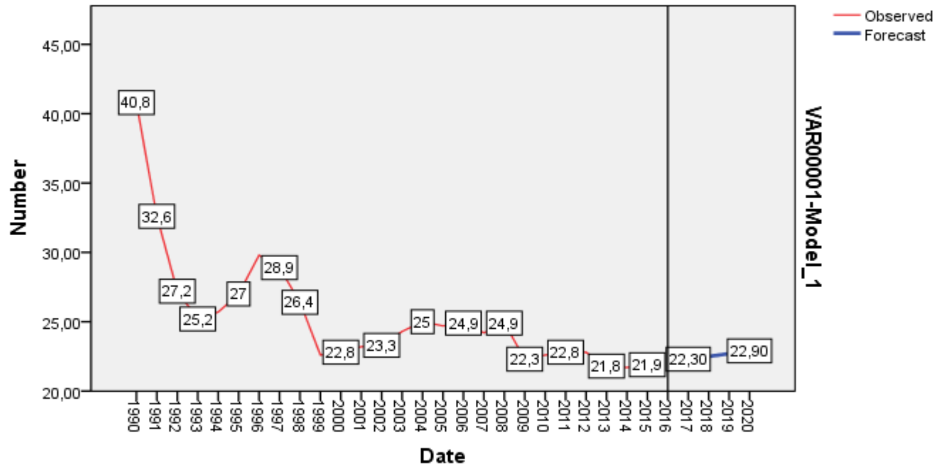

Figure 13. Final energy consumption's forecast in Romania

Source: Personal contribution using IBM-SPSS software

5. Conclusion

Environment protection represents a great challenge for the humanity. The greatest global economic actors have their own interests in managing this problem and adopt contradictory positions.

EU is one of those actors interested in decreasing pollution and finding new energy clean sources. The Europe 2020 Strategy has exact goals regarding climate and energy. Moreover, EU succeeded in achieving some of these goals starting to 2015.

On the other hand, there are great disparities related to climate and energy goals between Member States. This is why the achieving of all Strategy's goals in 2020 is not sure.

Romania has good performances in the environment protection and the clean energy promoting. Unfortunately, the performance of this country has to be put into balance with the economic trend.

The statistical data used in the analysis cover a long enough time period to obtain pertinent forecasts of the four specific indicators regarding climate and energy. Romania will improve its performance until 2020, even that other Member States will face to difficulties in achieving them.

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On a New Inequality Related to Consecutive Primes

Reza Farhadian[1]

Abstract: Let p_n be the n-th prime. In this note, first we study some well-known conjectures related to consecutive primes p_n and p_{n+1} as the Cramér's, Firoozbakht's, Andrica's, Granville's and Farhadian's conjectures. Afterward, we present a new inequality related to consecutive primes p_n and p_{n+1}, which is weaker than the Firoozbakht's conjecture.

Keywords: Primes; Cramér's conjecture; Firoozbakht's conjecture; Andrica's conjecture; Granville's conjecture; Farhadian's conjecture.

JEL Classification: C002

1 Introduction and Preliminary

An interesting subsequence of integers is the prime numbers sequence. Let

$$p_1 = 2, \qquad p_2 = 3,\ p_3 = 5,\ p_4 = 7, p_5 = 11, p_6 = 13,\ p_7 = 17, \ldots$$

are successive primes in their natural ordering, and in general, let p_n be the n-th prime. There are many conjectures on consecutive primes p_n and p_{n+1} , that some interesting of these conjectures are Andrica's, Cramér's, Granvile's, Shank's, Farhadian's, Firoozbakht's conjectures and etc. These unsolved problems are as follows:

Cramér's conjecture (1936)

This conjecture presented by the Swedish mathematician Harald Cramér in 1936 (Cramér, 1936, pp. 23–46). The Cramér's conjecture asserts that $p_{n+1} - p_n = O(\log^2 p_n)$, or in other words

$$\lim_{n\to\infty} sup \frac{p_{n+1}-p_n}{\log^2 p_n} = 1. \quad (1)$$

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In fact already in 1920, as a weaker statement, Cramér under the Riemann Hypothesis proved that $p_{n+1} - p_n = O(\sqrt{p_n} \log p_n)$ (Cramér, 1920, pp. 1–32). Afterward, in the mid 1930's, Cramér proposed a probabilistic model for primes that leads to very precise predictions of the asymptotic properties of primes (Cramér, 1936, pp. 23–46; Pintz, 2007, pp. 361–376). Using his probabilistic model, Cramér showed that the probability that a given integer m should be a prime is approximately $\frac{1}{\log m}$. Also, Cramér proved that for random primes P_n, with probability 1, we have $\lim_{n\to\infty} sup \frac{P_{n+1}-P_n}{\log^2 P_n} = 1$. This result, restated for true primes p_n and constitutes the above well-known Cramér's conjecture.

Firoozbakht's conjecture (1982)

This conjecture presented by the Iranian mathematician Farideh Firoozbakht in 1982 (Ribenboim, 2004). The Firoozbakht's conjecture states that the sequence $\left\{p_n^{\frac{1}{n}}\right\}_{n\geq 1}$ is strictly decreasing, which means that for every $n \geq 1$, we have

$$p_{n+1}^{\frac{1}{n+1}} < p_n^{\frac{1}{n}}. \tag{2}$$

The Firoozbakht's conjecture was verified for all primes below 4×10^{18} (Kourbatov, 2015, pp. 283–288). By Theorem 1 from (Kourbatov, 2015), if the Firoozbakht's conjecture holds, then

$$p_{n+1} - p_n < \log^2 p_n - \log p_n - 1, \quad \forall n > 9. \tag{3}$$

Hence, the Firoozbakht's conjecture implies the Cramér's conjecture.

Andrica's conjecture (1986)

This conjecture presented by the Romanian mathematician Dorin Andrica in 1986 (Andrica, 1986, pp 44–48). The Andrica's conjecture states that for every $n \geq 1$, we have

$$\sqrt{p_{n+1}} - \sqrt{p_n} < 1. \tag{4}$$

The Andrica's conjecture is similar to the another unsolved problem (Guy, 1994; Jakimczuk, 2011) that

$$\lim_{n\to\infty}\left(\sqrt{p_{n+1}} - \sqrt{p_n}\right) = 0 \tag{5}$$

Clearly, if the relation (5) be true, then the Andrica's conjecture is true for large n. However, the Andrica's conjecture is an interesting conjecture related to the consecutive primes, but it is weaker than the Firoozbakht's conjecture (Ferreira, 2017, Consequence 3.4). Furthermore, in 2015, C. A. Ioan and A. C. Ioan showed that the Andrica's conjecture is equivalent to $\sqrt{p_{n+1}} - \sqrt{p_n} < \left(\frac{p_n}{p_{n+1}}\right)^{\alpha}$ with $\alpha > 0$ (Ioan, & Ioan, 2015, pp. 149–153). They showed that a good estimate for α is $-\frac{1}{2} sup \frac{\log(\sqrt{p_{n+1}} - \sqrt{p_n})}{\log\sqrt{p_{n+1}} - \log\sqrt{p_n}}$, and they obtained the constant α by used the *Wolfram Mathematica software* and on the basis of the first 10^5 primes, the estimate value of α is equal to $\alpha \approx 2.2811$ (Ioan, & Ioan, 2015, pp. 149–153). Recently, in 2017, C. A. Ioan proved that the Andrica's conjecture is equivalen to $\sqrt{p_{n+1}} - \sqrt{p_n} < \left(\frac{{p_{n+1}}^{p_n}}{{p_n}^{p_{n+1}}}\right)^{\alpha}$ with $\alpha > 0$ (Ioan, 2017, pp. 198-202). Similar to the previous case, he showed that in this case a best estimate for α is $-\frac{1}{2} sup \frac{\log(\sqrt{p_{n+1}} - \sqrt{p_n})}{p_{n+1}\log\sqrt{p_n} - p_n\log\sqrt{p_{n+1}}}$. Moreover, the estimate value of the constant α on the basis of the first 10^5 primes is equal to $\alpha \approx 0.0018$ (Ioan, 2017, pp. 198-202).

Granville’s conjecture (1995)

This conjecture presented by the British mathematician Andrew Granville in 1995 (Granville, 1995, pp. 12–28). This conjecture states that for large n, we have

$$p_{n+1} - p_n \leq M(\log p_n)^2. \tag{6}$$

for some constant $M > 1$. Also, a good estimate for M is $2e^{-\gamma} \approx 1.2292$, where $e = 2.71828 \ldots$ is the base of natural logarithm and $\gamma = 0.57721 \ldots$ is the Euler–Mascheroni constant. We believe that if the Granville’s conjecture, holds, then prove of the Cramér’s conjectures is possible. Sometimes, the Granville’s conjecture showed by the form of $p_{n+1} - p_n \leq M(\log n)^2$ that this is sharper than the inequality (6); but as $n \to \infty$ the both form are equivalent.

Farhadian’s conjecture (2016)

This conjecture presented by the author in 2016 (Rivera, 2016)[1] and states that for $n > 4$, we have

$$p_n^{\left(\frac{p_{n+1}}{p_n}\right)^n} < n^{p_n}. \tag{7}$$

[1] Retrieved from http://www.primepuzzles.net/conjectures/conj_078.htm.

Note that sometimes the Farhadian's conjecture showed by the general form $p_n^{\left(\frac{p_{n+1}}{p_n}\right)^n} \leq n^{p_n}$; but we know that the right side of this inequality is a rational number and the left side of it is a integer number. So, the strict inequality (7) is better than the general non-strict form of it. The Farhadian's conjecture is implies the Cramér's, Firoozbakht's, Andrica's and Granville's conjectures and some other conjectures in this subject[1]. Recently, In 2017 R. Farhadian and R. Jakimczuk proved that the Farhadian's conjecture is true for almost all primes (Farhadian, & Jakimczuk, 2017, pp. 559 – 564). Consequently, the Firoozbakht's, Cramér's, Andrica's and Granville's conjecture also is true for almost all primes.

However, the above unsolved problems appears difficult, but gradually we realize that this difficulty is not perennial. In the next section, we will present some new results related to the Firoozbakht's conjecture.

2. The Main Results

In this section we prove the main results. First, consider the following theorem.

Theorem 1. *For every* $n \geq 1$, *we have*

$$p_{n+1} < p_n^{\frac{n+1}{n}\left(\frac{\log p_{n+1}}{\log p_n}\right)}. \tag{8}$$

Proof. Clearly, we have

$$n\log p_{n+1} < (n+1)\log p_{n+1}, \qquad \forall n \geq 1 \tag{9}$$

Since $\frac{\log p_n}{\log p_n} = 1$, so we can write the inequality (9) by the following form

$$n log p_{n+1} < (n+1) log p_{n+1} \times \overbrace{\left(\frac{log p_n}{log p_n}\right)}^{1} = \frac{(n+1) log p_{n+1}}{log p_n} log p_n, \tag{10}$$

We take the exponential of the inequality (10), we obtain

$$p_{n+1}{}^n < p_n^{(n+1)\frac{\log p_{n+1}}{\log p_n}}, \ \forall n \geq 1, \tag{11}$$

Consequently, we have $p_{n+1} < p_n^{\frac{n+1}{n}\left(\frac{\log p_{n+1}}{\log p_n}\right)}$ for $n \geq 1$.

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[1] See (Ferreira, & Mariano, 2017). Some consequences of the Firoozbakht's conjecture. Second version, arXiv:1604.03496v2 & (Rivera, 2016). Retrieved from http://www.primepuzzles.net/conjectures/conj_078.htm.

Corollary 1. *The sequence* $\left\{p_n^{\frac{1}{n\log p_n}}\right\}_{n\geq 1}$ *is strictly decreasing.*

Proof. By the Theorem 1, we know that $p_{n+1} < p_n^{\frac{n+1}{n}\left(\frac{\log p_{n+1}}{\log p_n}\right)}$, for $n \geq 1$. By $(\frac{1}{(n+1)\log p_{n+1}})$-power of the both sides of this inequality, we obtain

$$p_{n+1}^{\frac{1}{(n+1)\log p_{n+1}}} < p_n^{\frac{1}{n\log p_n}}, \quad \forall\, n \geq 1 \tag{12}$$

which means that the sequence $\left\{p_n^{\frac{1}{n\log p_n}}\right\}_{n\geq 1}$ is strictly decreasing.

Remark 1. The inequality (8) as well as slightly weaker than the Firoozbakht's conjecture.

Proof. By the inequality (8) we know that $p_{n+1} < p_n^{\frac{n+1}{n}\left(\frac{\log p_{n+1}}{\log p_n}\right)}$, for every integer $n \geq 1$. Besides, by the Firoozbakht's conjecture, we know that

$$p_{n+1} < p_n^{\frac{n+1}{n}}, \quad \forall n \geq 1 \tag{13}$$

Since $\frac{\log p_{n+1}}{\log p_n} > 1$, hence $p_n^{\frac{n+1}{n}} < p_n^{\frac{n+1}{n}\left(\frac{\log p_{n+1}}{\log p_n}\right)}$ and proof is complete.

Lemma 1. $\lim_{n\to\infty} \log\frac{p_{n+1}}{p_n} = 0.$

Proof. By the well-known *Prime Number Theorem*, we know that $\lim_{n\to\infty}\frac{p_{n+1}}{p_n} = 1$. Also, it is well-known that if $f(x)$ be a continuous function and A_n be an arbitrary sequence, then $\lim_{n\to\infty} f(A_n) = f\left(\lim_{n\to\infty} A_n\right)$. Since the $f(x) = \log x$ is a continuous function, so we have $\lim_{n\to\infty}\log\frac{p_{n+1}}{p_n} = \log\left(\underbrace{\lim_{n\to\infty}\frac{p_{n+1}}{p_n}}_{1}\right) = 0.$

Theorem 2.

$$p_{n+1} < p_n^{\frac{n+1}{n}\left(\frac{\log p_{n+1}}{\log p_n}\right)} \sim p_n^{\frac{n+1}{n}}. \tag{14}$$

where the symbol "$\sim$" means limit equivalence as $n \to \infty$.

Note that to prove the Theorem 2, the following well-known relations will be used:

- $\exp(\log x) = x, \quad \forall x \in (-\infty, +\infty).$
- For every sequence Q_n, always we have

  $\lim_{n\to\infty}\exp(\log Q_n) = \exp\left(\lim_{n\to\infty}\log Q_n\right) = \exp\left(\log(\lim_{n\to\infty} Q_n)\right).$

Now, consider the proof of Theorem 2:

Proof. By the Theorem 1, we know that $p_{n+1} < p_n^{\frac{n+1}{n}\left(\frac{\log p_{n+1}}{\log p_n}\right)}$, for $n \geq 1$. Now, we prove that

$$p_n^{\frac{n+1}{n}\left(\frac{\log p_{n+1}}{\log p_n}\right)} \sim p_n^{\frac{n+1}{n}},$$

Hence, we have

$$\lim_{n\to\infty} \frac{p_n^{\frac{n+1}{n}\left(\frac{\log p_{n+1}}{\log p_n}\right)}}{p_n^{\frac{n+1}{n}}} = \lim_{n\to\infty} \frac{\exp\left(\log\left(p_n^{\frac{n+1}{n}\left(\frac{\log p_{n+1}}{\log p_n}\right)}\right)\right)}{p_n^{\frac{n+1}{n}}}$$

$$= \lim_{n\to\infty} \frac{\exp\left(\frac{n+1}{n}\times\frac{\log p_{n+1}}{\log p_n}\times\log p_n\right)}{p_n^{\frac{n+1}{n}}}$$

$$= \lim_{n\to\infty} \frac{\exp\left(\frac{n+1}{n}\times\log p_{n+1}\right)}{p_n^{\frac{n+1}{n}}} = \lim_{n\to\infty} \frac{p_{n+1}^{\frac{n+1}{n}}}{p_n^{\frac{n+1}{n}}} = \lim_{n\to\infty} \left(\frac{p_{n+1}}{p_n}\right)^{\frac{n+1}{n}}$$

$$= \lim_{n\to\infty} \exp\left(\log\left(\frac{p_{n+1}}{p_n}\right)^{\frac{n+1}{n}}\right) = \lim_{n\to\infty} \exp\left(\frac{n+1}{n}\times\log\left(\frac{p_{n+1}}{p_n}\right)\right)$$

$$= \exp\left(\overbrace{\lim_{n\to\infty}\frac{n+1}{n}}^{1} \times \underbrace{\overbrace{\lim_{n\to\infty}\log\frac{p_{n+1}}{p_n}}^{0}}_{by\ lemma\ 1}\right) = \exp(0) = 1.$$

Therefore as $n \to \infty$, we have $p_{n+1} < p_n^{\frac{n+1}{n}\left(\frac{\log p_{n+1}}{\log p_n}\right)} \sim p_n^{\frac{n+1}{n}}$.

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The Relationship between Renewable and Nonrenewable Energy Consumption and Economic growth in G7 countries: Evidence from Bootstrap Panel Causality Test

Uğur Korkut Pata[1], Harun Terzi[2]

Abstract: In this study, both renewable and nonrenewable energy consumption and economic growth relations were examined by the bootstrap panel Granger causality method covering the period 1996-2014 for G7 countries. The findings show a unidirectional causality moving from renewable energy consumption to economic growth in Germany and Japan, and a bidirectional causality between these two variables in France, Italy and the United Kingdom. Regarding nonrenewable energy consumption, unidirectional causality moving from nonrenewable energy consumption to economic growth in Canada and the United States, and the causality in the opposite direction is valid in the United Kingdom and Germany. Also in Japan, there is a bidirectional causality relationship between these two variables. As a result, energy consumption is an important factor for G7 countries' economic growth.

Keywords: G7 Countries; Nonrenewable Energy Consumption; Renewable Energy Consumption; Panel Bootstrap Causality.

JEL Classification: C23; Q20; Q43

1. Introduction

The 1973 oil crisis that led to increased inflation, high unemployment rates and decreasing growth rates revealed that energy consumption had a considerable influence on economic growth. Countries trying to reduce their oil dependency began to seek new energy sources. Due to global warming and increased air pollution since the 20th century, sustainable economic growth and development became economically important. Due to both reasons, today, developed countries encourage the use of renewable sources of energy such as solar, wind, biomass and hydropower to reduce greenhouse gas emissions (GHG) instead of the use of non-renewable energy sources that pollute the air such as oil and coal.

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Renewable energy is not only directly included in production as an input, but it also indirectly affects economic growth. In 2014, the renewable energy sector employed 9.2 million people. The number of people employed is expected to rise to 24.4 million by 2030 (IRENA, 2016a). In addition, the global GDP is expected to rise from 0.6% to 1.1%, and global welfare is expected to rise between 2.7% to 3.7% by 2030 due to the increased consumption of renewable energy (IRENA, 2016b). According to International Energy Outlook (2016), the consumption of renewable energy, the most rapidly increasing source of energy, will increase by an average of 2.6% per year between 2012 and 2040. In cases where the countries around the world sustain their energy plans and policies, the share of renewable

energy consumption in total energy consumption, which amounted to 18.4% in 2014 will rise to 21% in 2030 (IRENA, 2016a).

The Group of Seven (G7) refers mostly to advanced industrial countries: Canada, France, Germany, Italy, Japan, the United Kingdom (UK) and the United States (US). These countries constituted 46% of the global GDP and 10% of the population in 2015 (World Bank, 2017). In line with the Kyoto Protocol signed in 2005, G7 countries support increasing renewable energy consumption to reduce GHG emissions. The G7 countries account for about 47% of the renewable energy consumption and about 30% of the primary energy consumption around the world (BP, 2016). New technologies in these countries have reduced GHG emissions and the high costs of renewable energy consumption.

There are four basic hypotheses depending on the direction of the causality relationship between energy consumption (EC) and economic growth (GDP): (a) According to the conservation hypothesis which assumes the presence of a unidirectional causality from GDP to EC, energy conservation policies can be implemented without causing any harm to the economy; (b) According to the growth hypothesis which assumes the presence of a unidirectional causality from EC to GDP, energy conservation policies damage economic growth. Therefore, energy consumption should be encouraged to achieve economic growth; (c) The feedback hypothesis assumes that bidirectional causality exists between EC and GDP. Therefore, energy conservation policies damage economic growth; (d) The neutral hypothesis assumes that there is no causality relationship between the two variables. Therefore, energy conservation policies have no adverse effect on economic growth.

2. Literature Review

The first empirical analysis of the relationship between energy consumption and economic growth was performed by Kraft and Kraft (1978) for the United States. Since the first quarter of the 21st century, the relationship between renewable energy consumption and economic growth has begun to be tested empirically. Narayan and Smyth (2008) reported that energy consumption and capital stock affected economic growth positively for the G7 countries both in the short and long run. Tugcu et al. (2012) used the ARDL bounds testing and Hatemi-J causality test and found that the growth hypothesis was valid only in Japan in terms of nonrenewable energy consumption. They also confirmed the validity of the conservation hypothesis for Germany and the feedback hypothesis for the UK and Japan in terms of renewable energy consumption. Chang et al. (2015) examined the causality relationship between renewable energy consumption and economic growth and confirmed the validity of the conservation hypothesis for France and the UK, and the growth hypothesis for Germany and Japan. Mutascu (2016) also examined the causality relationship between energy consumption and economic growth and found that the feedback hypothesis was valid in Canada, Japan, and the United States while the conservation hypothesis was valid in France and Germany. Destek and Okumus (2017) divided energy consumption into the consumption of oil, coal and natural gas and examined their relationship with economic growth. Their findings revealed that the growth hypothesis was valid in Italy, Japan and the United States for oil consumption, the conservation hypothesis was valid in the UK, and the feedback hypothesis was valid in Germany. The growth hypothesis was valid in Italy, Japan, the UK and the United States, and the feedback hypothesis was valid in Germany in terms of natural gas consumption. Finally, the validity of the growth hypothesis was confirmed for Canada, and the conservation hypothesis was confirmed in the United States for the relationship between coal consumption and economic growth.

There is no consensus in the literature for the G7 countries due to the different methods and periods. There are various studies on the relationship between energy consumption and economic growth; however, the number of those examining the relationship between renewable and nonrenewable energy consumption and economic growth in G7 countries is limited. To the best of the authors knowledge, this is the first study to investigate the relationship between both renewable and nonrenewable energy consumption and economic growth in G7 countries using the panel bootstrap Granger causality test. This study aims to investigate the energy-growth nexus in G7 countries using the panel bootstrap Granger causality test.

3. Data and Methodology

In this study conducted using annual data covering the period 1996-2014 for G7 countries, nonrenewable energy (primary) consumption (PEC), renewable energy consumption (REC), and gross domestic product (GDP) were used as variables. REC was obtained from the International Energy Agency (IEA, 2016), and GDP and PEC were obtained from the World Development Indicators (WDI, 2017). The data regarding the real GDP is expressed in millions of dollars in constant 2010. PEC and REC were expressed in terms of kilograms of equivalent petrol (kgoe) and million tonnes of oil equivalent (mtoe), respectively. All variables are included in the analysis in the logarithmic form.

3.1. Cross-Sectional Dependence Test

Due to globalization and financial integration, an economic event taking place in a country can affect the whole world. This situation is called cross-sectional dependence. The Lagrange multiplier (LM) test introduced by Breusch and Pagan (1980) tests the existence of cross-sectional dependence among countries. The following panel data is used for the LM test:

$$y_{it}=\alpha_i+\beta_i^{'}x_{it}+u_{it} \text{ for } i=1,2\ldots,N;\ t=1,2,\ldots,T \quad (1)$$

In Equation. (1), i represents cross-section, t represents time, α_i is the constant term, β_i is the slope coefficient and x_{it} is the (kx1) vector of explanatory variables. In the LM test, the null hypothesis H_0: $Cov(u_{it},u_{jt})=0$ states that there is no cross-sectional dependence, while the alternative hypothesis $H_{alternative}$: $Cov(u_{it},u_{jt})\neq 0$ states the existence of cross-sectional dependence. The LM test statistics are calculated using the following equation:

$$LM=T\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\rho}_{ij}^2,\ \chi^2_{N(N-1)/2} \quad (2)$$

In Equation (2), $\hat{\rho}$ represents the pair-wise correlation of the ordinary least squares (OLS) residuals obtained from Equation (1) for each cross-section. The LM test is valid when the cross-section (N) is relatively small and time (T) is large enough. Pesaran (2004) developed the CD_{LM} test, which is valid when N and T are sufficiently large. As a scaled version of the LM test, the CD_{LM} test is shown in Equation (3):

$$CD_{LM}=\left(\frac{1}{N(N-1)}\right)^{0.5}\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}(T\hat{\rho}_{ij}^2-1),\ N(0,1) \quad (3)$$

Because Pesaran's (2004) CDLM test is valid with a large N and a small T, a more general CD test was developed which is valid when T→∞, and N→∞. Equation (4) shows the cross-sectional dependence (CD) test.

$$CD=\sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\rho}_{ij}\right),\ N(0,1) \quad (4)$$

Pesaran et al. (2008) modified the LM test using the exact mean and variance of the LM statistics. Equation (5) shows this test called bias-adjusted LM.

$$LM_{adj}=\sqrt{\frac{2}{N(N-1)}}\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\frac{(T-k)\hat{\rho}_{ij}^2-\mu_{Tij}}{\upsilon_{Tij}^2},\ N(0,1) \quad (5)$$

In Equation (5), k is the regressor; μ_{Tij} and υ^2_{Tij} are the exact mean and variance of the $\left(T\text{-}k\right)\hat{\rho}^2_{ij}$ respectively. The LM_{adj} test yields reliable results when the CD test is insufficient in certain cases when the population average pair-wise correlations are zero, although the underlying individual population pair-wise correlations are nonzero (Pesaran et al., 2008). For each of the four cross-sectional dependence tests, the null hypothesis states that there is no cross-dependence among countries, while the alternative hypothesis states otherwise.

3.2. Slope Homogeneity Test

When the parameters are considered homogeneous without regarding the heterogeneity, differences of the countries included in the analysis are neglected and the estimations become inconsistent. Regarding homogeneity, $\tilde{S}$ statistics was first developed by Swamy (1970) to analyze whether slope coefficients are homogenous or not. Pesaran and Yamagata (2008) improved the $\tilde{S}$ statistics and implemented the delta ($\hat{\Delta}$) homogeneity test, which is valid for large samples, and delta-adj ($\hat{\Delta}_{adj}$) homogeneity test valid for small samples. Swamy's (1970) $\tilde{S}$ statistics is estimated using the following equation:

$$\tilde{S}=\sum_{i=1}^{N}\left(\hat{\beta}_i-\tilde{\beta}_{WFE}\right)'\frac{x_i'M_\tau x_i}{\tilde{\sigma}_i^2}\left(\hat{\beta}_i-\tilde{\beta}_{WFE}\right) \quad (6)$$

In Equation (6), M_τ is the identity matrix, $\tilde{\sigma}_i^2$ is the estimator of σ_i^2, and β_i and $\tilde{\beta}_{WFE}$ are pooled OLS and the weighted, fixed-effect pooled estimation obtained from Equation (1), respectively. Equation (7) shows the delta test using $\tilde{S}$ statistics.

$$\tilde{\Delta}=\sqrt{N}\left(\frac{N^{-1}\tilde{S}-k}{\sqrt{2k}}\right) \quad (7)$$

As long as (N, T) $\rightarrow \infty$, $\sqrt{N/T}\rightarrow\infty$ under the null hypothesis, error terms have normal distribution and the $\tilde{\Delta}$ test, which has asymptotic standard normal distribution is valid.

$$\tilde{\Delta}_{adj}=\sqrt{N}\left(\frac{N^{-1}\tilde{S}-E(\tilde{z}_{iT})}{\sqrt{var(\tilde{z}_{iT})}}\right) \quad \mathbf{(8)}$$

In Equation (8), in the $\tilde{\Delta}_{adj}$ test, $E(\tilde{z}_{iT})$ is equal to k and $var(\tilde{z}_{iT})$ is equal to 2k(T-k-1)/T+1. When N is larger than T, the results of the $\tilde{\Delta}_{adj}$ test become less reliable (Pesaran and Yamagata, 2008). In homogeneity tests, the null hypothesis states that slope coefficients are homogenous (H_0: $\beta=\beta_i$), whereas the alternative hypothesis states that slope coefficients are heterogeneous (H_0: $\beta\neq\beta_i$).

3.3. Kónya bootstrap panel Granger causality test

In Kónya's (2006) bootstrap panel Granger causality test, the series are included in the analysis at their level without taking account of their stationarity and cointegration characteristics. In this causality test, the panel is assumed heterogeneous, i.e., countries are assumed to have different characteristics. Therefore, the Granger causality test can be performed for each country. When there is cross dependence between countries, the OLS estimators are not effective and reliable. In this causality test, this problem is resolved by using Zelner's (1962) seemingly unrelated regression (SUR) equation. The following equations show the VAR system solved using the SUR method:

$$y_{1,t}=\delta_{1,1}+\sum_{l=1}^{mly_1}\beta_{1,1,l}y_{1,t-l}+\sum_{l=1}^{mlx_1}\mu_{1,1,l}x_{1,t-l}+u_{1,1,t},\ y_{N,t}=\delta_{1,N}+\sum_{l=1}^{mly_1}\beta_{1,N,l}y_{N,t-l}+\sum_{l=1}^{mlx_1}\mu_{1,N,l}x_{i,t-l}+u_{1,N,t}$$

$$x_{1,t}=\delta_{2,1}+\sum_{l=1}^{mly_2}\beta_{2,1,l}y_{1,t-l}+\sum_{l=1}^{mlx_2}\mu_{2,1,l}x_{1,t-l}+u_{2,1,t}\,,$$

$$x_{N,t}=\delta_{2,N}+\sum_{l=1}^{mly_2}\beta_{2,N,l}y_{N,t-l}+\sum_{l=1}^{mlx_2}\mu_{2,N,l}x_{N,t-l}+u_{2,N,t} \qquad (10)$$

In Equation (9) and Equation (10), N represents the cross section, t represent time, δ represents constant terms and β and μ are coefficients. The lag length is l, and u represents the error terms. When all $\mu_{1,i}$ values are not equal to zero, but all $\beta_{2,i}$ values are equal to zero, there is unidirectional Granger causality running from X to Y. Similarly, when all $\beta_{2,i}$ values are not equal to zero, but all $\mu_{1,i}$ values are equal to zero, Y is the Granger cause of X. When all of them are equal to zero, there is no causality between the variables (Kónya, 2006). Using Akaike and Schwarz information criteria (ACI and SCI), one can determine the optimal lag lengths, which represent mly_1, mly_2 and mlx_1, and mlx_2. In Kónya's (2006) causality test, a country-specific bootstrap table of critical values is used instead of asymptotic table critical values.

4. Empirical Results

4.1. Results of Cross-Sectional Dependence and Homogenous Tests

Before analyzing the relationships between the variables, cross-sectional dependence and homogeneity have to be tested, and the causality and cointegration tests should be performed based on the results of the cross-sectional dependence and heterogeneity. Table 1 shows the results of the cross-sectional dependence and homogeneity tests.

Table 1. Results of Cross-Sectional Dependence and Homogeneous Tests

Test	Statistic	P-value
LM	51.10***	0.00
CD_{LM}	4.64***	0.00
CD	5.22***	0.00
LM_{adj}	6.66***	0.00
$\widehat{\Delta}$	8.95***	0.00
$\widehat{\Delta}_{adj}$	10.00***	0.00
*** significant at 1% level.		

According to the statistics of the LM, $CD_{LM,}$ CD and LM_{adj} tests, there is cross-dependence among the countries at a 1% significance level. The presence of cross-sectional dependence is expected between these seven countries which are the most industrially developed countries of the world. In this sense, any energy or growth shock in one of the G7 countries affects the other countries, too. The statistics of the $\widehat{\Delta}$ and $\widehat{\Delta}_{adj}$ tests show that there is heterogeneity at a 1% significance level. Therefore, we used Kónya's (2006) bootstrap panel Granger causality test which takes account of the cross-dependence and heterogeneity while examining the relationship between energy consumption and economic growth.

4.2. Results of Kónya Bootstrap Panel Granger Causality Test

Kónya's (2006) bootstrap panel Granger causality test was performed to test the relationships between renewable and nonrenewable energy consumption and economic growth with T=19 for each G7 country. The optimal lag length was found by using the SIC information criteria taking a maximum lag of 3.

Table 2. Results of Kónya Bootstrap Panel Granger Causality Test

Country	REC→GDP				GDP→REC			
	Statistic	Critical Values			Statistic	Critical Values		
		1%	5%	10%		1%	5%	10%
Canada	0.04	50.29	30.44	21.83	3.90	28.49	18.56	14.67
France	**6.75***	16.86	9.20	6.30	**3.72****	4.27	2.48	1.79
Germany	**53.17****	53.69	35.27	27.57	0.23	16.02	8.88	6.22
Italy	**11.73****	16.93	10.23	7.24	**19.12****	21.91	15.08	12.06
Japan	**15.63****	22.77	10.55	6.81	0.17	9.94	4.98	3.30
UK	**7.67***	14.96	8.30	6.19	**15.80*****	8.27	6.19	5.33
US	5.00	40.71	24.94	18.27	12.48	53.20	35.48	24.32
***Significant at 1% level; **significant at 5% and * significant at 10% level. k is the optimal lag length selected by Schwarz information criteria (SIC). Bootstrap critical values are based on 10.000 replications.								

Table 2 shows the causality relationships between renewable energy consumption and economic growth. According to Table 2, there is a bidirectional causality in France, Italy and the UK, which confirms the validity of the feedback hypothesis for these countries. We also found a unidirectional causality running from renewable energy consumption to economic growth for Japan and Germany which supports the growth hypothesis. Implementation of energy conservation policies will damage economic growth in France, Italy, the UK, Japan and Germany.

Table 3. Results of Kónya Bootstrap Panel Granger Causality Test

Country	PEC→GDP				GDP→PEC			
	Statistic	Critical values			Statistic	Critical Values		
		1%	5%	10%		1%	5%	10%
Canada	**15.73*** **	7.23	3.67	2.45	0.44	35.52	24.41	19.80
France	0.67	22.15	13.58	10.47	0.00	25.37	17.96	14.55
Germany	4.41	20.05	10.02	6.03	**14.25** **	23.48	12.83	9.22
Italy	13.92	59.62	38.17	30.92	11.77	56.73	32.59	23.51
Japan	**3.79** **	6.93	3.70	2.59	**12.23*** **	9.67	5.48	3.83
UK	0.97	12.60	7.76	5.73	**8.77** *	15.55	10.43	8.57
US	**7.39*** **	5.59	2.99	2.02	0.01	26.02	16.71	13.22

***Significant at 1% level; **significant at 5% and * significant at 10% level. k is the optimal lag length selected by Schwarz information criteria (SIC). Bootstrap critical values are based on 10.000 replications.

Table 3 shows the causality relationships between non-renewable energy consumption and economic growth. According to the table, there is a bidirectional causality for Japan which confirms the validity of the feedback hypothesis for this country. We also found a unidirectional causality running from economic growth to nonrenewable energy consumption for Germany and the UK which supports the conservation hypothesis for these countries. There is also a unidirectional causality from nonrenewable energy consumption to economic growth in Canada and the US. This finding confirms the validity of the growth hypothesis for these countries. The neutral hypothesis which states there is no causality between two variables is valid in Canada and the US for renewable energy consumption and in Italy and France for nonrenewable energy consumption. Policies encouraging nonrenewable energy consumption may support economic growth in Canada, Japan and the US. In terms of the relationship between renewable energy consumption and economic growth, the validity of the growth hypothesis was confirmed for two of the seven countries, while the validity of the feedback hypothesis was confirmed for two countries. In terms of the causality relationship between nonrenewable energy consumption and economic growth, the growth hypothesis was found to be valid for two of the seven countries, while the conservation hypothesis was valid for two countries, and the feedback hypothesis was valid for one country. In terms of the causality relationship between both types of energy consumption and economic growth, the validity of the growth hypothesis was confirmed for four countries, and the validity of the feedback hypothesis was confirmed for four countries.

5. Conclusion

This study examined the relationships between renewable and nonrenewable energy consumption and economic growth for G7 countries using Kónya's (2006) bootstrap panel Granger causality test that takes account of cross-sectional dependence and heterogeneity. First, cross-sectional dependence and heterogeneity tests were performed. Their results indicated that the countries have different structures and any energy and economic growth shock in any of the countries could affect other G7 countries. The results of the causality test confirmed the validity of the feedback hypothesis for Japan. This validation was that, the conservation hypothesis for the UK and Germany and the growth hypothesis for Canada and the US reflect a relationship between nonrenewable energy consumption and economic growth. In terms of the relationship between renewable energy consumption and economic growth, the feedback hypothesis was found to be valid in France, Italy and the United Kingdom, while the growth hypothesis was valid in Japan and Germany. The findings also confirmed the validity of the neutral hypothesis for France and Italy for nonrenewable energy consumption and for Canada and the US for renewable energy consumption.

In each of the G7 countries, renewable or nonrenewable sources of energy interact with economic growth. The findings show that energy conservation policies affect economic growth of these countries adversely. Therefore, energy policies made in the G7 countries are of high importance for their economic growth. For these countries trying to reduce their greenhouse gas emissions, encouraging the use of renewable energy sources is important for increasing the environmental quality.

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