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Renewable and non-renewable energy consumption and total factor productivity growth: The case of G20 countries

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ABSTRACT

The purpose of this paper is to investigate the short and long-run relationships between renewable, non-renewable energy consumption (NREC) and economic growth. This study highlights the importance of renewable energy consumption to improve the total factor productivity (TFP) in G20 countries spanning on 2002-2018. Using the approach of panel Feasible Generalized Least Squares (PFGLS) cross-section and period weight and FGLS cross-section and period sur robust, we have divided the sample in three groups: G20, G7 and G20-G7. The findings show that there is a negative effect of Renewable Energy Consumption (REC) on TFP in G7 and a positive effect in the other groups. Our main results indicate that there is a strong significant and positive relationship between REC and TFP growth in the long run in the hull G20 countries. But, in the G7, there is a negative relationship due to the negative effect in the environment. The results of granger causality tests indicate the existence of one-way causality from NREC to TFP in G20 and G20-G7, while from TFP to NREC in G7. To boost overall productivity and maintain sustainable development, all nations must invest in renewable energy.

Contribution/ Originality: The originality of this research lies in the statement that when the goal is to achieve strong growth, little attention is paid to the type of energy used. As developed countries in the G7 call for replacing non-renewable energies with renewable energies, but they continue to consume the first energy excessively.

1. INTRODUCTION

Energy is one of the mains elements of human life. Without energy, life will be very difficult. It seems to be necessary to heating, electricity and produce goods and services. Today, there is an acceleration of development of the over the last decades. Energy, as the important commodities in world trade, has proved to have an ever more important role in economic growth of many countries. From economic point of vu, energy is considered as one of factors of production. Indeed, it is used to achieving sustainable economic growth. There are many studies have focused on the role of energy in economic. The first study is the study of Kraft and Kraft (1978) which have analyzed the relationship of energy and growth national product (GNP). After this study, various researchers have investigated the link between energy and economic activity (Akinlo, 2008; Balat, 2008; Balcilar, Ozdemir, & Arslanturk, 2010; Zaidi, Jbir, & Gmidene, 2014). Stern (1993) as ecologic economist believed that energy is the most important growth

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factor, while, labor and capital are mediating factors that permit energy to be used. Overall, the study of economic growth and energy consumption based on four hypothesis with strong implication for growth and energy policy:

Hypothesis (1) called the feedback hypothesis and implies a bidirectional causation between the two variables.

Hypothesis (2) is the growth hypothesis unidirectional causation from energy to economic growth.

Hypothesis (3) called conservative hypothesis implies unidirectional causation from economic growth to energy consumption.

Hypothesis (4) is neutrality hypothesis and means no causation between two variables.

This paper based on the hypothesis (2) that advances the view that energy consumption promotes economic growth, precisely; the demand of renewable energy consumption propelled with sustainable growth measured by the growth of total factors productivity. Tugcu (2013) indicated that the Solow (1956) and Solow (1957) studies of exogenous growth have showed that the total factor productivity (TFP) constitutes the main concept of advances in production technology, efficiency and growth of managerial skills combination. After Solow (1956) and Solow (1957) many studies (Easterly & Levine, 2001; Jerzmanowski, 2007; Jones, 1997; Miller & Upadhyay, 2000) have investigated this idea and confirmed that the power of production factors is explained essentially by the TFP. This is meaning that there is a positive relation between energy consumption and total factor productivity as showed (Chien & Hu, 2007; Hisnanick & Kymn, 1992; Turner & Hanley, 2011). In this paper, we focus on the impact of energy consumption on total factor productivity growth by disaggregating energy consumption into renewable and non-renewable energy components in G20 countries using the panel feasible generalized least squares (PFGLS) (Bai, Choi, & Liao, 2021) method. The PFGLS method is relatively recent, and a few studies used this method. Furthermore, we introduce other explicative variables, such as openness, foreign direct investment, education index and Information and information and communications technologies for development to determine the transmission channels of the impact of energy on TFP growth. The remain of this paper is organized as follows: section two gives a brief literature review of TFP-energy relationship. Section three presents' data and model. Section four analyses the empirical results. Finally, section five concludes.

2. A BRIEF REVIEW OF LITERATURE

As we indicated above, the economic literature has widely discussed the relationship between energy and economic growth. But a few studies have focused on the link between TFP and renewable and non-renewable energy. The first study on causality between energy consumption and total factor productivity was introduced by Schurr (1983) and Jorgenson (1984). After that, many researchers have studied the link between different types of energy consumption and TFP (Abou, 2020; Afonso, Marques, & Fuinhas, 2017; Al-Iriani, 2006; Bhattacharya, Paramati, Ozturk, & Bhattacharya, 2016; Boyd & Pang, 2000; Costantini & Martini, 2010; Da Silva, Cerqueira, & Ogbe, 2018; Giang, Xuan, Trung, & Que, 2019; Hasanov, Mikayilov, Bollino, & Liddle, 2019; Hisnanick & Kymn, 1992; Ladu & Meleddu, 2014; Soava, Mehedintu, Sterpu, & Raduteanu, 2018; Tugcu, 2013; Tugcu & Tiwari, 2016).

By the analysis of the impact of petroleum and non-petroleum consumption on TFP growth in the American manufacturing sector in1958-1985 period, Hisnanick and Kymn (1992) proved that disaggregated energy causes the decline of TFP. The same conclusion was funded by Moghaddasi and Pour (2016) for Iranian agriculture sector between 1974 and 2012. Whereas, the study of Fuglie (2008) showed that there is a positive impact of energy consumption on TFP growth for the American agriculture sector between 1948 and 2004.

Tugcu (2013) by using the cointegration method, conclude that the increase of one percent in the in the share of renewable energy consumption in total energy consumption increases the total factor productivity growth of Turkish economy by 0.663% in the short-run and 0.818% in the long-run. Ladu and Meleddu (2014) and Soava et al. (2018) have investigated the direction of causality between energy consumption and TFP. They proved the existence of bi-directional causality between variables.

By separating between different types of energy consumption (renewables and non-renewables), many other researchers have focused on the impact of these types of energy consumption on TFP growth. They found a difference

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between results according to the countries and the period of the study. Indeed, for the BRICS[1] countries during 1992 to 2012, Tugcu and Tiwari (2016) indicated that there is causality only in one direction from non-renewables energy consumption to TFP growth in Brazil and South Africa and the renewable energy consumption does not seem to be a determinant of TFP growth for all countries. The same result was founded by Afonso et al. (2017) in their study of the impact of renewable and non-renewable energy consumption on gross domestic product per capita (GDP) in 28 countries between 1995 and 2013. For Bhattacharya et al. (2016); Da Silva et al. (2018) and Soava et al. (2018) there is only a positive effect of renewable energy on economic growth for respectively 38 top renewable energy consuming countries[2], Sub-Saharan Africa countries and 28 Europeans countries.

For Saudi Arabia country, Hasanov et al. (2019) have studied the relationship between energy consumption and TFP growth. Their finding indicates that the TFP growth positively affect the energy consumption in the long-run.

Overall, the studies of relationship of types of energy consumption and TFP growth show different results according to the sample of countries and the considered period. But, following these results, we can see that there is a consensus that the impact of energy consumption on TFP growth is positive.

3. DATA AND MODEL

3.1. Data

Our study sample is composed by the largest industrialized countries and emerging markets(G20). We used a panel data set, which compounds G20 countries for the period 1990-2018. Data, description and source of the variables used in this study are shown in Table 1.

Table 1. Description of data and source.

Variables	Descriptions	Source
$GTFP_{it}$	Growth of total factors productivity	Economy database, the conference board
REC_{it}	Renewable energy consumption is the share of renewable energy in total final energy consumption.	World bank
$NREC_{it}$	Fossil fuel (Comprises coal, oil, petroleum, and natural gas products.) energy consumption (% of total)	World bank
$EDUI_{it}$	Education index	World development indicator, world bank
FDI_{it}	Foreign direct investment, net inflows (% of GDP)	International financial statistics and balance of payments databases, world bank,
$Open_{it}$	Merchandise trade (% of GDP) all in current U.S. dollars.	UNCTAD stat trade in goods and services
IDI_{it}	ICT-development index	IUT (International union of tenants) database

Hereafter, all variables are taken in natural logarithms, most estimated coefficients should be interpreted as a constant elasticity of the dependent variable with respect to the independent variables. The data have been obtained from the World Bank's World Development Indicators (WDI) and Economy database, The Conference Board[3].

3.2. Model Specification

Following many empirical studies (Apergis & Payne, 2010, 2012; Matei, 2017) our study is based on the following function:

[1] The BRICS countries are Brazil, Russia, India, China, and South Africa.

[2] The 38 top renewable energy consuming countries are: Australia, Austria, Belgium, Brazil, Bulgaria, Canada, Chile, China, the Czech Republic, Denmark, Finland, France, Germany, Greece, India, Ireland, Israel, Italy, Japan, Kenya, Republic of Korea, Mexico, Morocco, the Netherlands, Norway, Peru, Poland, Portugal, Romania, Slovenia, South Africa, Spain, Sweden, Thailand, Turkey, Ukraine, the United Kingdom, and the United States.

[3] https://www.conference-board.org/data/economydatabase/total-economy-database-productivity

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$$TFP = F(REC, NREC, X')$$

Where TFP is the total factors productivity, REC is renewable energy consumption, NREC is non-renewable energy consumption and X' is vector of controls variables: Openness (Open), foreign direct investment (FDI), Education index (EDU) and Information and Communications Technologies development index (IDI). Subscripts "i" refer to the country, and "t" to the time period. This model has its origins in the theoretical Cobb-Douglas production function with constant return to scales. Dividing all variables by Labor force (LF) we obtain the PTF function as following:

$$TFP_{it} = INTERCEPT + \beta_1 LNREC_{it}s + \beta_1 LNNREC_{it} + \sum_{k=3}^{6} \beta_k X'_{Kit} + \varepsilon_{it}$$

Where, $\sum_{k=3}^{6} \beta_k X'_{it} = \beta_3 EDU_{it} + \beta_4 FDI_{it} + \beta_5 Open_{it} + \beta_6 IDI_{it}$

4. EMPIRICAL RESULTS AND ECONOMIC ANALYSIS

4.1. Panel Unit Root test

In the econometric analysis, to ensure robustness for the common components of variables, several unit root tests, including The Levin-Lin-Chu test (LLC), Im, Pesaran and Shin test (IPS), augmented Dickey and Fuller (ADF) and the Phillips and Perron (PP) tests were employed. Table 2 presents the results of panel unit root tests.

Table 2. Panel unit root tests.

Variables \ Test		Individual intercept				Individual intercept and trend				Stationarity
		LLC	IPS	ADF-fisher	PP-fisher	LLC	IPS	ADF-fisher	PP-fisher	Integ. order
TFP	Level	-7.11 (0.00)	-9.05 (0.00)	157.7 (0.00)	241.3 (0.00)	--	--	--	--	I(0)
REC	Level	1.28 (0.90)	3.60 (0.99)	21.96 (0.98)	23.4 (0.97)	-0.52 (0.29)	0.43 (0.66)	34.79 (0.62)	42.46 (0.28)	I(1)
	First difference	-8.68 (0.00)	-11.3 (0.00)	197.02 (0.00)	337.1 (0.00)	--	--	--	--	
NREC	Level	-1.93 (0.03)	0.89 (0.81)	35.7 (0.57)	42.6 (0.28)	-0.26 (0.39)	0.50 (0.69)	34.40 (0.63)	38.75 (0.43)	I(1)
	First difference	-10.2 (0.00)	-10.87 (0.00)	185.7 (0.00)	307.5 (0.00)	--	--	--	--	
EDUI	Level	-4.54	1.61	42.24	68.55	-4.47	-1.57	56.34	43.10	I(0)
OPEN	Level	-2.78 (0.00)	-1.38 (0.08)	49.80 (0.09)	45.34 (0.19)	-1.5898 (0.05)	-3.17 (0.00)	65.97 (0.00)	133.2 (0.00)	I(0)
FDI	Level	-2.86 (0.00)	-4.59 (0.00)	81.51 (0.00)	109.40 (0.00)	--	--	--	--	I(0)
IDI	Level	-4.015 (0.00)	0.75 (0.77)	33.46 (0.68)	45.11 (0.19)	1.03 (0.84)	-0.27 (0.39)	35.83 (0.57)	55.81 (0.03)	I(1)
	First difference	-7.63 (0.00)	-10.3 (0.00)	176.6 (0.00)	379.4 (0.00)	--	--	--	--	

Note: Numbers within the parenthesis indicate the p-value, if plus-value more than 5% the variable is stationary. I(0) mean integrated in the level, I(1) integrated in the first level.

According to the Panel Unit Root Test results presented in Table 2, some variables are I(0) such as labor force (EDUI) and TFP in some countries, while other variables; renewable and non-renewable energy consumption are I(1).

4.2. Panel Cointegration Tests

Since there is a difference between integration orders of the variables as shown by unit root test results, we will apply the cointegration tests in the case of panel data (bounds tests) developed by Pesaran, Shin, and Smith (2001). This test can verify know whether the variables in the model are cointegrated or not. Table 3 presents the results of cointegration tests.

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Table 3. Panel cointegration tests.

Pedroni residual cointegration test **Series:** ***TFP LNREC LNNREC EDU OPEN FDI***					
Null hypothesis: No cointegration		**Statistic**	**Prob.**	**Weighted**	
				Statistic	**Prob.**
Common AR coefs (Within-dimension)	Panel v-statistic	-0.98	0.83	-2.77	0.99
	Panel rho-statistic	-2.98	0.00	-1.92	0.02
	Panel PP-statistic	-13.92	0.00	-12.67	0.00
	Panel ADF-statistic	-13.01	0.00	-11.20	0.00
Individual AR coefs (Between-dimension)	Group rho-statistic	-0.58	0.27		
	Group PP-statistic	-17.73	0.00		
	Group ADF-statistic	-13.25	0.00		
Kao residual cointegration test Series: *TFP LNREC LNNREC EDU OPEN FDI*					
Null hypothesis: No cointegration		T-statistic	Prob.		
ADF		-7.62	0.00		
Johansen Fisher panel cointegration test Series: TFP LNREC LNNREC EDU OPEN FDI					
Hypothesized; No. of CE(s)		Fisher stat.*			
		(From trace test)	Prob.	(From max-eigen test)	Prob.
None		515.5	0.00	304.9	0.00
At most 1		268	0.00	162.8	0.00
At most 2		140.5	0.00	79.57	0.00
At most 3		84.12	0.00	52.86	0.05
At most 4		60.56	0.01	46.31	0.16
At most 5		69.83	0.00	69.83	0.00

Note: * Probabilities are computed using asymptotic Chi-square distribution.

According to the results shown in Table 3, the long-term coefficients reveal that renewable energy consumption has a positive and significant impact on TFP in G20 countries. Also, the results of diagnostic test indicate that there is no serial correlation, heteroscedasticity problems.

In order to avoid the heteroscedasticity and endogeneity of autocorrelation of the residuals, we use Feasible Generalized Least Squares (FGLS) with the Three Stage Least Squares (3SLS) and the Generalized Method of Moments (GMM). Figure 1 presents the Total Factors Productivity (TFP) residuals.

From Figure 1, we denote that the higher volatility is for the countries number 1, 14, 15 and 17, referring to the original order in the estimated database, these countries are respectively Argentina, Japan, Korea Rep, and Russia. The other countries of the group have TFP residuals relatively stable.

Overall, to investigate the impacts of energy consumption sources (renewable and non-renewable) on the TFP, many studies used the aggregate energy consumption. In this research, we focus on the role of renewable energy consumption, non-renewable energy consumption, trade openness education level and FDI on Total factor productivity growth by using the PFGLS model for the G20 countries.

4.3. Panel Feasible Generalized Least Squares (PFGLS) Estimation

Given that G7 countries are the main countries used the technology development than emerging countries and to distinguish between countries that are making great efforts to increase reliance on the consumption of renewable energy and those that rely primarily on the consumption of non-renewable energy, we divide our sample in two group: G7 group and G20-G7 group (the others member of countries of G20 other than G7). Overall, three group are studied in this paper: The G7 countries, G20-G7 countries and all countries of G20 together. Table 4a, 4b and 4c report the results of PFGLS estimation for the three group.

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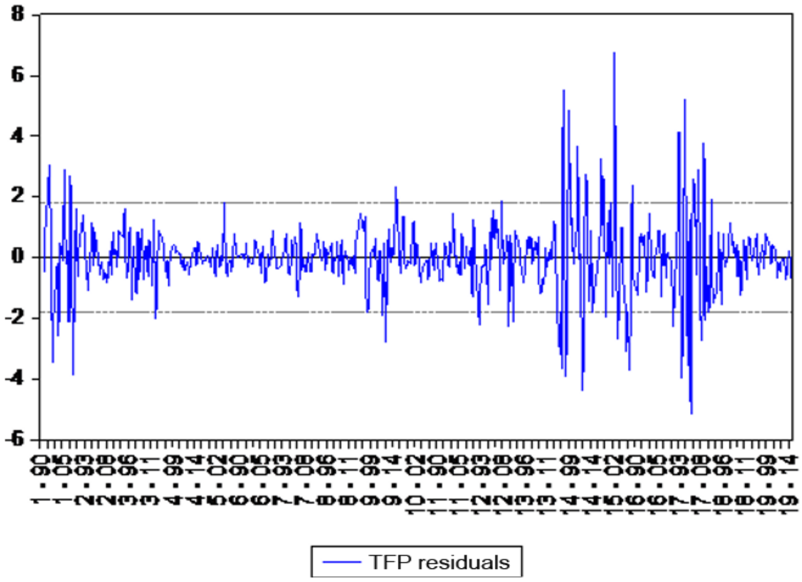

Figure 1. TFP residuals.

Table 4a. Estimation results of group 1 (G20).

Panel estimation methods	**M1** **POLS**	**M 2** **PFGLS (Cross-section weights)**	**M 3** **PFGLS (Period weights)**	**M 4** **PFGLS (Period SUR, robust)**
Exogenous variables	**Coef. (Prob.)**	**Coef. (Prob.)**	**Coef. (Prob.)**	**Coef. (Prob.)**
LNREC	0.48*** (0.00)	0.08 (0.42)	0.46*** (0.00)	0.43*** (0.00)
LNNREC	1.67* (0.07)	0.99* (0.07)	2.03*** (0.00)	1.40** (0.01)
EDUI	7.47*** (0.00)	-0.21 (0.90)	6.74*** (0.00)	-0.13*** (0.00)
FDI	-0.13 (0.10)	-0.04 (0.42)	-0.10 (0.14)	5.75*** (0.00)
OPEN	0.01 (0.16)	0.002 (0.71)	0.013* (0.05)	0.01*** (0.00)
IDI	-0.72*** (0.00)	-0.27*** (0.00)	-0.69*** (0.00)	-0.62*** (0.00)
C	-10.02** (0.01)	-2.57 (0.28)	-11.10*** (0.00)	-7.87*** (0.00)
Obs(T=14, N=19)	285	285	285	285
R^2	0.20	0.15	0.25	0.58
F-statistic	11.85 (0.00)	8.50 (0.00)	15.79 (0.00)	18.87 (0.00)
Durbin-Watson test (DW)	1.35	1.34	1.16	2.00
Specification test perfuming suitable method of estimation				
Redundant fixed effects tests	(5.21) (0.00)	--	--	--
Hausman test	(4.47) (0.61)	--	--	--
Cross-section heteroscedasticity LM test	--	Likelihood ratio 127.4 (0.00)	--	--
Period heteroscedasticity LM test	--	--	Likelihood ratio 62.50 (0.00)	--
Residual cross-section dependence test				
Breusch-Pagan LM test Pesaran scaled LM test Pesaran CD test	470.57 (0.00) 16.19 (0.00) 15.32 (0.00)			

Note: ***, ** and * respectively denote significance levels of 1%; 5% and 10%.- p-values are in brackets.

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Table 4b. Estimation results of group 2 (G20-G7).

Panel estimation methods	M1 POLS	M 2 PFGLS (Cross-section weights)	M 3 PFGLS (Period weights)	M 4 PFGLS (Cross-section SUR, robust)
Exogenous variables	**Coef.(Prob.)**	**Coef.(Prob.)**	**Coef.(Prob.)**	**Coef.(Prob.)**
LNREC	0.66*** (0.00)	0.73*** (0.00)	0.62*** (0.00)	0.66*** (0.00)
LNNREC	1.64 (0.32)	5.25*** (0.00)	2.75* (0.05)	2.03** (0.03)
EDUI	-0.23* (0.09)	0.00 (0.97)	-0.15 (0.22)	-0.21*** (0.00)
FDI	11.91*** (0.00)	-2.32 (0.31)	11.60*** (0.00)	10.79*** (0.00)
OPEN	0.03** (0.01)	0.04*** (0.00)	0.03*** (0.00)	0.03*** (0.00)
IDI	-0.96*** (0.00)	-0.25 (0.08)	-1.03*** (0.00)	-0.87*** (0.00)
C	-13.21* (0.05)	-23.52*** (0.00)	-17.25*** (0.00)	-14.40*** (0.00)
Obs (T=14, N=12)	180	180	180	180
R^2	0.26	0.35	0.33	0.66
F-statistic	10.39 (0.00)	15.62 (0.00)	14.37 (0.00)	58.39 (0.00)
Durbin-Watson test (DW)	1.41	1.21	1.21	1.81
Specification test perfuming suitable method of estimation				
Redundant fixed effects tests	4.82 (0.00)	--	--	--
Hausman test	2.20 (0.89)	--	--	--
Cross-section heteroscedasticity LM test	--	Likelihood ratio 64.98 (0.00)	--	--
Period heteroscedasticity LM test	--	--	Likelihood ratio 38.48 (0.00)	--
Residual cross-section dependence test				
Breusch-Pagan LM Pesaran scaled LM Pesaran CD	145.55 (0.00) 6.92 (0.00) 6.25 (0.00)			

Note: ***, ** and * respectively denote significance levels of 1%; 5% and 10%.- p-values are in brackets.

Table 4c. Estimation results of group 3 (G7).

Panel estimation methods	M1 POLS	M 2 PFGLS (Cross-section weights)	M 3 PFGLS (Period weights)	M 4 PFGLS (Cross-section SUR, robust)
Exogenous variables	**Coef.(Prob.)**	**Coef.(Prob.)**	**Coef.(Prob.)**	**Coef.(Prob.)**
LNREC	-0.25 (0.25)	-0.29 (0.13)	-0.47*** (0.00)	-0.29** (0.04)
LNNREC	-0.91 (0.26)	-1.17 (0.10)	-0.09 (0.60)	-1.32*** (0.00)
EDUI	-0.01 (0.91)	-0.03 (0.58)	-0.01* (0.09)	-0.01 (0.68)
FDI	8.18** (0.01)	9.87*** (0.00)	3.20*** (0.00)	9.97*** (0.00)
OPEN	-0.01 (0.32)	-0.01 (0.20)	0.02*** (0.00)	-0.01** (0.03)
IDI	-0.13 (0.36)	-0.27* (0.05)	-0.006 (0.90)	-0.37** (0.01)
C	-1.17 (0.72)	-0.35 (0.90)	-2.16*** (0.00)	1.04** (0.01)
Obs (T=14, N=7)	105	105	105	105
R^2	0.08	0.15	0.64	0.54
F-statistic	1.60 (0.15)	2.87 0.01	29.09 0.00	19.60 0.00
DW	2.02	1.87	1.60	2.06
Specification test perfuming suitable method of estimation				

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Panel estimation methods	M1 POLS	M 2 PFGLS (Cross-section weights)	M 3 PFGLS (Period weights)	M 4 PFGLS (Cross-section SUR, robust)
Exogenous variables	**Coef.(Prob.)**	**Coef.(Prob.)**	**Coef.(Prob.)**	**Coef.(Prob.)**
Redundant fixed effects tests	35.41 (0.00)	--	--	--
Hausman test	3.18 (0.78)	--	--	--
Cross-section heteroscedasticity LM test	--	Likelihood ratio 13.09 (0.06)	--	--
Period heteroscedasticity LM test	--	--	Likelihood ratio 93.79 (0.00)	--
Residual cross-section dependence test				
Breusch-Pagan LM Pesaran scaled LM	202.3 (0.00) 23.30 (0.00)			

Note: ***, ** and * respectively denote significance levels of 1%; 5% and 10%. - p-values are in brackets.

4.4. Results Interpretations

Tables 4 (a, b and c) summarize the main results of estimation models. Four panel estimation methods were implemented as follow:

- M1, panel ordinary lest square (POLS).
- M2 and M3, panel feasible generalized lest square (PFGLS) Cross-section and period weights respectively.
- M4, PFGLS period SUR or cross-section SUR, robust.

We have used these methods (M1, M2, M3, and M4) in order to reach the best estimate of the model parameters. In fact, the econometric point of view highlights that the panel least square method (POLS) represents the best estimator under natural conditions. But, the existence of errors in the hypothesis needs the estimation by the ordinary least squares (OLS) method. Bai et al. (2021) concluded that, the feasible GLS estimator (PFGLS) is more efficient than the ordinary least squares (POLS) in the presence of heteroskedasticity, serial and cross-sectional correlations.

The results of model M1 shows that there is a significative coefficients of explicative variables for three groups, but overall, the model is not significative as indicate R2 (0.204, 0.260) and DW (0.620, 0.463) due to autocorrelation and heteroscedasticity problems.

The models M2 and M3 show that the PFGLS period or cross-section weights by using the Redundant Fixed Effects Tests can be suitable method for estimation in our case.

The results of model M4 which use the PFGLS specification is the robust methods. This model is able to correct the cross-section heteroskedasticity and the contemporaneous correlation.

In order to decide between fixed or random effects, we employ the Hausman test (Hausman, 1978). If the probability value(P-value) less than 0.05, we reject the null hypothesis. The results of Hausman test in Table 4, for G20, G20-G7 and G7 groups are respectively 4.4704 (0.6133), 2.205(0.899) and 3.18 (0.7860). From this result, we can conclude that there is a random effect in models. The results of the random effects tests in the three Table 4a, 4b and 4c showed that the cross-section effects and period effects are redundant. Indeed, the F statistic and P-value for the three groups are respectively 5.215(0.0000), 4.816 (0.0000) and 35.41(0.0000).

Overall, following the results of specification test in the last column of every Table 4a, 4b and 4c, we can choose the estimation of model M4 to examine the relationship between the variables in our study.

These results prove that there is a positive and statistically significant relationship between the renewable and non-renewable energy consumption and TFP growth in both G20 and G20-G7 groups. But this relationship is negative in G7 group.

Also, the results of PFGLS estimation, indicated that the variables trade, renewable and non-renewable energy consumption positively affect the total factors productivity in two groups (G20 and G20-G7), whereas the Foreign Direct Investment positively affect TFP in all group of countries.

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4.5. Granger Causality Tests Results

In this part of study, we have explored the dynamic causal relationship between TFP and exogenous variables mainly renewable energy consumption in G20, G7 and G20-G7 countries. The division of countrifies in three groups, helps us in showing the direction of Granger causality, in order, to understand the direction of the relationship between the studied variables.

We tested the granger casualty of variables based on the two following models:

$$TFP_{i,t} = \sum_{j=1}^{m} \alpha_j \, TFP_{it-j} + \sum_{j=1}^{m} \beta_j \, X'_{it-j} + \varepsilon_{it}$$

$$X'_{i,t} = \sum_{j=1}^{m} \delta_j \, TFP_{it-j} + \sum_{j=1}^{m} \gamma_j \, X'_{it-j} + \mu_{it}$$

Where TFP represents the Total factor productivity, X' the variables used, i = 1,2, …., 20 represents the twenty countries of G20, and t = 2002, 2, …,2017 represents time in years ε_{it} and μ_{it} the residuals. The results of the Granger causality tests are reported in Table 5.

Table 5. Pairwise granger causality tests.

Null hypothesis	G20		G20-G7		G7	
	F-statistic (Prob.)	Causality result	F-statistic (Prob.)	Causality result	F-statistic (Prob.)	Causality result
LNREC does not Granger cause TFP	6.27*** (0.00)	LNREC → TFP	5.23*** (0.00)	LNREC → TFP	0.40 (0.67)	
TFP does not Granger cause LNREC	0.93 (0.39)		1.30 (0.27)		0.09 (0.91)	
LNNREC does not Granger cause TFP	0.48 (0.61)		0.99 (0.37)		0.44 (0.64)	LNNREC ← TFP
TFP does not Granger cause LNNREC	2.29 (0.10)		0.32 (0.72)		3.53** (0.03	
FDI does not Granger cause TFP	3.45** (0.03)	FDI → TFP	2.58* (0.07)	FDI → TFP	2.42* (0.09)	FDI → TFP
TFP does not Granger cause FDI	0.50 (0.60)		0.56 (0.56)		1.32 (0.27)	
EDUI does not Granger cause TFP	1.02** (0.36)	EDUI ↔ TFP	1.17 (0.31)	EDUI ← TFP	2.75* (0.07)	EDUI → TFP
TFP does not Granger cause EDUI	3.16** (0.04)		3.21** (0.04)		0.11 (0.89)	
OPEN does not Granger cause TFP	12.9*** 0.00	OPEN → TFP	6.02*** (0.00)	OPEN → TFP	6.96*** (0.00)	OPEN↔ TFP
TFP does not Granger cause OPEN	1.48*(0.23)		0.39 (0.67)		4.80** (0.01)	
IDI does not Granger cause TFP	1.79 (0.16)		1.31 (0.27)		0.85 (0.43)	
TFP does not Granger cause IDI	0.07 (0.93)		0.12 (0.88)		1.16 (0.32)	

Note: ***, ** and * are the significance acquired respectively at 1%, 5% and 10%.
LNREC: Log of renewable energy consumption.
LNNREC: Log of non-renewable energy consumption.

4.6. Results Interpretations

The results of granger causality tests are summarize as following:

- The results indicate one-way causality from LNREC to TFP in G20 and G20-G7 while from TFP to LNREC in G7. These results are agreed with the results of Tugcu and Tiwari (2016) wish found a bi-directional causal link between non-renewables and TFP growth in Brazil and South Africa by using panel bootstrap Granger

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causality test. Also, Hasanov et al. (2019) have shown that TFP has a statistically significant impact on energy consumption in the long-run.

- In the three groups of countries there is one-way causality from FDI to TFP. First, FDI exerts a major influence on economic growth. Second, by stimulating inflows of FDI, the recipient countries can encourage economic growth. This finding is in line with Irandoust (2001) which prove that FDI and output are causally related in the long run for Norway and Sweden.
- In G20, there is two-way causality between EDUI and TFP. This bi-directional causality between variables means that, EDUI affects TFP and also TFP influences EDUI. but this causality has one-way direction from TFP to EDUI in G20-G7 and from EDUI to TFP in G7.
- Finally, the result given one-way causality from OPEN to TFP in G20 and G20-G7, and two-way causality between OPEN and TFP in G7. This means that an increase in openness between countries directly affects economic growth throw TFP in all groups of countries, moreover, productivity also stimulates further openness in G7. These results are proved by Abizadeh and Pandey (2009) which find that that trade openness, represented by the openness variable, has a direct and positive influence on the growth of TFP in the Organization for Economic Cooperation and Development (OECD) countries.

5. DISCUSSION AND CONCLUSION

In this paper, we analyzed the relationship between renewable and non-renewable energy consumption and economic growth through the total factor productivity (TFP) in G20 countries from 1990 to 2018. We estimated the share contribution of energetic variables to TFP growth by using classical and augmented production functions. This work highlights that energy use and output growth are, theatrically and empirically connected. It is based on a comparison between renewable and non-renewable energy sources effects on TFP growth in order to determine which type of energy consumption is more important for economic growth in G20 countries. In addition to the causality tests, we estimated the Panel Feasible Generalized Least Squares (PFGLS) for three group in our sample.

Our findings reveal that there is a strong significant and positive long relationship between renewable and non-renewable energy consumption and TFP growth in G20 group and G20-G7. The results have shown that the following variables FDI, trade, renewable and non-renewable energy consumption positively affects the TFP growth. Moreover, in all group of countries, Foreign Direct Investment affect TFP with an important significative and positive elasticity coefficient. For G7 group, the results have proved that energy consumption negatively affects TFP growth. This is meaning that in the high-level developed countries energy consumption affect negatively the growth of TFP. This finding can be explained by that the growth of TFP of these countries may be affected by the Co2 emissions of renewable and non-renewable energy consumption (environment pollution) and also, that developed countries enhance TFP, not by energy consumption, but, by other factors like education, information and technologies development, foreign direct investment …etc. Overall, understanding the contribution and impact of renewable and nonrenewable energy consumption on economic growth has an important influence in the formulation of both energy and environmental policies. Indeed, the G7 countries must investigate more in other factors of production than energy consumption and replace the non-renewable energy consumption to reduce the environment pollution.

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