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Bassem Kahouli (kahoulibassem@yahoo.fr)
Hail Community College : University of Hail
Benayan Bani Alrasheedy
Hail Community College : University of Hail
Nahla Chaaben
Hail Community College : University of Hail
Rabab Triki
Hail Community College : University of Hail

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Understanding the Relationship between Electric Power Consumption, Technological Transfer, Financial development and Environmental Quality.

Bassem Kahouli [a,b,*] , Benayan Bani Alrasheedy [a], Nahla Chaaben [a], Rabab Triki [a]

[a] University of Ha'il, Community College, Ha'il, Saudi Arabia.
[b] University of Sousse, Higher Institute of Finance and Taxation, Sousse, Tunisia.
kahoulibassem@yahoo.fr.

Abstract

This research paper attempts to investigate both the long-run and causality relationship among electric power consumption (EPC), technological transfer, financial development (FD), and environmental quality for the Saudi Arabia (KSA) economy from 1980 to 2019. In doing so, we propose a carbon emission function tested by incorporating multi-steps techniques such as autoregressive distributed lag (ARDL) has been exploited to determine the existence of cointegration or no; while vector error correction model (VECM) has been applied to decide the direction of causality. In this paper we have proposed two proxies of technological transfer, namely imported technology (MT) and Technical cooperation grants (TCG). The results indicate the existence of cointegration between the concerned series. Besides, the existence of a feed-back effect among variables (except TCG) in the long-run. However, in the short run feed-back effect exists among EPC and EnvQ; MT and EnvQ; EPC and MT. Thus, the paper provides original visions for policy makers to encourage the technological transfer by financing and supporting the electric energy sector which constitutes the main locomotive to improve the environment quality for the KSA.

Keywords: Electric power, Technology transfer, Environment, Financial development

JEL classification : C32, C52, O11, Q43

1. Introduction

In recent decades, climate change due to carbon (CO_2) emissions is one of the major environmental, political and economic challenges since it affects the whole world. Thus, it is disrupting national economies, degrading the environment, affecting lives, changing weather patterns, rising sea levels, and weather events are becoming more extreme, etc. (United Nations, 2018). Therefore, improved EnvQ represents an ecological, economical and sociological issue of importance and concern worldwide. Hence, humanity is required to think and act responsibly and determine sustainable solutions especially in countries with highly energy consumption and economic growth. That could be explained as the production process is conducted by the demand for energy. Whereas this demand in turn is conducted by demographic developments, level of economic activities, and by technological and structural changes (Yeager et al., 2011). Nevertheless, efforts to respond to the progressive energy demand coupled with the mitigation of climate change represent a hard task for governments that need several technological innovations, FD with a rational environmental policy.

In this paper we will focus on electricity as the main form of final energy used to power homes, transport, trades, communications and productions. According to Zhang et al. (2013) the electricity generation is the principal source of carbon, representing more than 40% of global CO_2 emissions that contribute to degradation of the EnvQ. In fact, in the KSA, growth and exports rely almost completely on industries that benefit from circumstantial advantages related to power and raw material provision, knowing that these resources will deplete over time. Furthermore, the Saudi industrial sector is heavily concentrated in these basic industries, as they represent 56% of GDP and more than 71%.

of exports, relying strongly on the KSA circumstantial advantages related to energy. In addition, the KSA economy aims to achieve significant performance for key factors of transformative industries such as innovation, ability to attract and retain talents and government regulations. This situation made the Kingdom fronted to many challenges such as improving the competitiveness of the electricity sector through restructuring and exploring power exportation opportunities, increasing the share of the renewable energy sector in local consumption and enhancing the competitiveness of the energy sector. In the same time, reducing environmental degradation by creating a friendly climate while balancing the need for reducing fiscal burden with need for focused incentives; in particular, reduce electricity consumption, are the main author challenges to the KSA. In this context, this study aims to investigate the role played by energy specifically EPC, technological transfer and FD on EnvQ. As well to understand the long-run and the causal relationships between variables, we applied a multi-steps methodology based mainly on ARDL and VECM Granger causality approach. This methodology supports to demonstrate the effects of relevant technology, financial and economic factors to promote the quality of the environment in the KSA. To the best of our knowledge, there has never been any endeavors to investigate both the long-run and the interactions among EPC, technological transfer, FD and EnvQ for the KSA economy.

The reminder of this manuscript is organized as below: Section 2 exposes a literature review on EPC, technological transfer, FD and EnvQ. Section 3 describes data and model specification. Section 4 provides econometrics methodology for this research paper. Section 5 reveals and discusses the empirical results. Section 6 recapitulates and endings by proposing certain recommendations and policy implications.

2. Literature review

The existing environment and energy literature have rarely examined the relationships among EPC, technological transfer, FD and EnvQ especially in the KSA economy. This current paper exposes specifically the most relevant studies which are related to our variables of interest by classified the existent reviews in three research strands. The first one examines the relationships among EPC, technological transfer and EnvQ. The second strand investigates the relationships between EPC, FD and EnvQ while the third explores the associations among FD, technology transfer and EnvQ. As Table1 proves, the discoveries of these studies are inconclusive.

2.1. EPC-technological transfer-environment nexus

The studies on the relationships among energy, technology and environment has been the recent trend in the environment and energy literature (Zang et al., 2013; Mariano et al., 2016; Wang and Wang., 2018; Pang and Tao, 2018; Kahouli, 2018; Rumayor et al., 2019; Zafar et al., 2020, Altıntas and Kassouri, 2020). To be more specific, Mansouri et al. (2013) have studied the Saudi electricity sector focused on 18 different forecast figures for CO_2 emissions engendered by electricity for each year from 2010 to 2025. They have suggested that Saudi government must declare objectives to reduce CO_2 emissions and to invest seriously in evolving its own progressions and innovations in energy technologies. In the case of China, Wang and Wang (2018) have investigated the relationship among MT and environmental degradation for the period 1980-2011. Based on the ARDL and the VECM they deduce that imported technologies principally lead to CO_2 emissions in the long-run. The findings have mentioned the existence of feed-back effects among MT and environment; energy use and environment. Furthermore, Hodson et al. (2018) have estimated the importance of technology innovation, the fuel prices, and CO_2 emissions on electric power productions from four U.S. energy-economic models through the year 2050. Results have shown that realizing innovation aims declines CO_2 emissions owing to improved energy efficiency.

In the same context, Cheng et al. (2019) have studied the associations among the developments of patents as a technological innovation indicator and CO_2 emissions for 36 OECD countries from 1996 to 2015 by using a panel quantile regression model. Empirical findings have shown that the coefficient values are not significant and even positive with CO_2 emissions at different quantile levels. Further, Ali et al. (2019) have investigated the Kuznets curve of Malaysia over a period of 1985 to 2016 by using the ARDL method. The results have suggested that improved technology can lead to a cleaner environment. Consequently, there are bi-directionally linked between environment and energy consumption as well as between structural changes and technological innovation. In another paper, Alola et al. (2019) have analyzed the role of renewable energy consumption and economic growth to ameliorate EnvQ by using ARDL approach to 16 European Union countries for the period 1997-2014. Empirical results have approved that renewable energy enhances EnvQ. Focusing in Thailand, Wattana and Wattana (2020) have developed three scenarios that represent penetration levels of electricity generated from renewable energy for the period 2018-2037. The results have indicated the importance of technology innovation in renewable energy that affects positively the electricity generation with a particular focus on energy security and CO_2 emissions mitigation potentials. Recently, Sinha et al. (2020) have studied the link between technological innovation and EnvQ in Middle East and North African (MENA) countries for the period of 1990-2017. They have used the Quantile cointegration and Quantile Autoregressive Granger causality. Empirical finding indicates mutual dependence among technological progression and ambient air pollution. More recently, Zameer et al. (2020) have explored the effects of technological innovation and energy use on CO_2 emissions in the Indian economy during the period 1985-2017 by employing the ARDL and the VECM methods. They have confirmed the existence of long-term cointegration and energy consumption positively stimulates CO_2 emissions. Whereas, technological innovation negatively reinforces environment quality in the long term.

2.2. EPC-FD-environment nexus

The relationship between EPC, FD and environment has been well proven this is last years for instance Sadorsky (2011); Shahbaz (2013); Farhani and Ozturk (2015); Kahouli and Omri, (2017); Cetin et al. (2018); Kahouli (2018); Xu et al. (2018); Ouyang et al. (2018); Wang (2019); Eren et al. (2019); Zang (2019); Shahbaz et al. (2020); Acheampong et al. (2020). Those studies across countries using both panel and time-series data by incorporating several econometric techniques like as correlation analysis, bivariate causation, unit root tests, multivariate cointegration, ARDL, VECM, ordinary least square (OLS), full modified OLS (FMOLS), dynamic OLS (DOLS), generalized method of moments (GMM), linear and non-linear dynamic panel models. Get started by Shahbaz (2013) who has explored the nexus among financial instability, environmental degradation and energy use in Pakistan from 1971 to 2009 by employing ARDL and VECM. The empirical results have shown that a long-run association among series can be identified as well as financial instability declines EnvQ. Likewise, Farhani and Ozturk (2015) have examined the causal relationship among CO_2 emissions, economic growth, energy consumption, and FD in Tunisia from 1971 to 2012 by applying ARDL and VECM. The empirical findings have indicated that the FD stimulates CO_2 emissions. Besides, Bekhit et al. (2017) explored the dynamic causal relationships between CO_2, FD and energy use for Gulf Cooperation Council (GCC) countries from 1980 to 2011. The results suggest a long-term causal relationship between CO_2 emissions and FD for all GCC countries except the United Arab Emirates. Consequently, there is a long-term and one-way direction causality from carbon emissions to energy consumption for some countries such as the KSA, UAE and Qatar. Thus, the financial systems of GCC countries should consider environmental aspects in their decisions while preserving economic growth. In the same line, Kahouli (2018) has studied the four-way associations linkages among EPC, CO_2 emissions, FD, R&D and real GDP for the Mediterranean countries from 1990 to 2016 by using SUR, 3SLS, and GMM estimators. Empirical results confirm the existence of strong feedback effects between variables. In the same context, Xu et al. (2018) have explored the contribution of FD to environmental degradation in the KSA by applying ARDL and VECM methods to observe the long-term causal relationship. The results have shown that FD contributes to the degradation of the quality of the environment and that EPC is the principal responsible for the environmental degradation in the KSA. Alternatively, the causality is mutual and bidirectional between long-term CO_2 emissions and FD. In another perspective, Shahbaz et al. (2020) have examined the link between EPC, FD and environment by using the Toda-Yamamoto causality test. The finding indicated that FD raises CO_2 emissions and real GDP is completely associated to environmental degradation. While, EPC improves the EnvQ. Acheampong et al. (2020) have explored the impact of the financial market and energy consumption on CO_2 emissions intensity. They have used the GMM technique for 83 countries over the period 1980-201, they have revealed that financial markets moderate growth and energy to stimulate environment degradation.

2.3. Financial development-technological transfer-environment nexus

In the recent literature, there are slight studies trying to investigate our third strand which purposes to study the link among FD, technology transfer and environment (Khan et al., 2018; Amri, 2018; Demir et al., 2019; Kahouli, 2019; Ibraheim, 2020; Nguyen et al., 2020; Avom et al., 2020; Aluko and Obalade, 2020). For instance, Khan et al. (2018) have examined the link among information and communication technology (ICT), FD, and EnvQ in emerging countries from 1990 to 2015 by employing mean group (MG) and augmented mean group (AMG) methods. The empirical findings have shown that the moderating impact of ICT and FD accelerate the environmental degradation. Likewise, Amri (2018) has studied the linkage between CO_2 emissions, ICT and FD, in Tunisia from 1975 to 2014 by using ARDL. Empirical results have indicated an insignificant impact of ICT on CO_2 emissions as a measure of pollution; FD negatively affects the EnvQ. In the case of Turkey, Demir et al. (2019) have used the ARDL cointegration approach to examine the relationship between FD, the number of national patents and CO_2 emissions from 1971 to 2013. The results have revealed that the relationship among the level of CO_2 emissions and the number of national patents represents an inverted U-curve. Therefore, FD has positive effects on CO_2 emissions. In another study, Ibraheim (2020) have studied the nexus between CO_2 emissions, technological innovation and FD in Egypt from 1971 to 2014 by using ARDL, FMOLS, DOLS and Toda-Yamamoto approaches. The empirical results have shown that technological innovation and alternative energy resources advance EnvQ, FD deteriorates it. The results from Toda-Yamamoto approach expose that environmental degradation generates technological innovation and FD generates environmental degradation. In the same order, Nguyen et al. (2020) have studied the effect of FD, ICT and innovation on EnvQ (proxied by CO_2 emissions) in selected 13 countries in the G20 from 2000 to 2014 by using FMOLS and Quantile Panel. The empirical findings have indicated that ICT has an unintended impact on EnvQ through FD. Recently, Avom et al. (2020) have tested how ICT influences EnvQ in 21 Sub-Saharan Africa (SSA) from 1996 to 2014. They have concluded that ICT has an unintended impact on EnvQ through energy use, trade and FD. More recently, Aluko and Obalade (2020) have explored the technology impact of FD on EnvQ in 35 in SSA countries for the period 198-2014 by using the AMG estimator. The empirical results have mentioned that FD has an unfavorable technology impact on EnvQ.

According to those studies the empirical findings are conflicted. Probably, the principal reason for these various results derives from the data, econometric approaches and the level of development of the country in which a study is being carried out. Thus, it is essential to carry out new exploration concerning the relationship between EPC, technological transfer, FD and EnvQ.

Table 1. Summary of empirical studies on EPC, technological transfer financial development and Environmental Quality relationship.

Author(s)	Country/Region	Period	Methodology	Empirical findings
EPC-technological transfer-environment nexus.				
Mariano et al. (2016)	BRICS and the G7 countries	1993-2010	Non parametric analysis (DEA)	Technology contributes efficient energy and low energy consumption helping to realize the best environment.
Wang and Wang (2018)	China	1980-2011	ARDL and VECM	Feed-back effects between MT and CO_2 emissions; energy consumption and CO_2 emissions.
Hodson et al. (2018)	USA	Through the year 2050.	16 models comparative cross sector analysis	Innovation decreases CO_2 emissions due to increased energy efficiency and low-carbon generation.
Cheng and al. (2019)	36 OECD countries	1996-2015	Panel quantile regression model	The coefficient values are not significant and even positive with CO_2 emissions at different quantile levels.
Alola et al. (2019)	16 Europeans countries	1997-2014	A panel ARDL approach	There is an influence of ITC on energy consumption that contributes to an effect on the environment perspective.
Zafar et al. (2020)	OCDE countries	1990-2015	Second generation methods	Energy consumption affects EnvQ and ITC declines CO_2.
Zameer et al. (2020)	Indian	1985-2017	ARDL and VECM	Energy positively enhances CO_2. Whereas, technological innovation negatively reinforces CO_2 in the long term.
EPC-FD-environment nexus.				
Shahbaz (2013)	Pakistan	1971-2009	ARDL and VECM	There are long-run relationships between variables and financial instability decrease EnvQ.
Farhani and Ozturk (2015)	Tunisia	1971-2012	ARDL and VECM	FD expenses of environmental pollution.
Bekhit et al. (2017)	GCC countries	1980- 2011	ARDL approach	There are long-term causal relationships among CO_2, FD for all GCC countries except the United Arab Emirates (UAE).
Xu et al. (2018)	Saudi Arabia	1971-2016	ARDL and VECM	FD contributes to the degradation of the EnvQ and EPC is the main responsible for the increase in CO_2 emissions.

Kahouli (2018)	Mediterranean countries	1990-2016	SUR, 3SLS and GMM	Existence of feedback effects between ECP, CO_2 and FD.
Cetin et al. (2018)	Turkey	1960-2013	Cointegration test and VECM	CO_2 is determined by EPC, and FD.
Wang (2019)	BRICS countries	1992-2013	GMM method	Energy consumption reduces environmental pollution and there is an N-shaped relationship between FD and pollution.
Eren et al. (2019)	India	1971-2015	DLOS	Positive impact of FD on EPC and a bidirectional causality between EPC and FD driven in the long run in India.
Shahbaz et al. (2020)	UAE	1975-2014	Cointegration test and TodaYamamoto causality test	FD increases CO_2 emissions and electricity improves the quality of the environment.
Acheampong et al. (2020)	83 countries	1980-2015	GMM approach and a comprehensive panel data	Financial markets develop moderate energy to influence CO_2 emission intensity.
FD-technological transfer-environment nexus.				
Khan et al. (2018)	Emerging countries	1990-2015	MG and AMG estimation methods	The moderating effect of ICT and FD stimulate the level of CO_2 emissions.
Amri (2018)	Tunisia	1975-2014	ARDL Cointegration	Insignificant impact of ICT on CO_2 emissions as a measure of pollution. However, FD negatively affects the EnvQ.
Demir et al. (2019)	Turkey	1971-2013	ARDL Cointegration	Inverted U-curve between CO_2 emissions and the number of national patents. FD effects positively on CO_2 emissions.
Ibraheim (2020)	Egypt	1971-2014	ARDL, FMOLS, DOLS, and Toda-Yamamoto approaches	Technological innovation and alternative energy resources improve EnvQ; FD deteriorates it.
Nguyen et al. (2020)	13 countries in G20 group	2000-2014	Quantitative analysis, OLS and Quantile Panel	ICT has an indirect effect on EnvQ through FD.
Avom et al. (2020)	21 Sub-Saharan Africa	1996-2014	Stochastic regression	ICT has an indirect effect on EnvQ through FD.
Aluko and Obalade (2020)	35 Sub-Saharan countries	1985-2014	Dumitrescu-Hurlin panel test	FD has an unfavorable technology effect on EnvQ.

3. Data and model specification

3.1. Data

In order to figure out the nexus between EPC, technological transfer, FD and EnvQ, diverse proxies have been employed to measure technology and EnvQ in the previous studies. This paper measures environmental quality (EnvQ) as CO_2 emissions from electricity and heat production, total (% of total fuel combustion). Likewise, electric power consumption (EPC) determines the production of power plants and combined heat and power plants (kWh per capita). To identify the technological transfer, we propose two proxies. The first proxy determines the imported technology (MT), we utilize computers, communications and other services (% of commercial service imports) including such activities as international telecommunications; computers. The second variable as a proxy of the technological transfer is technical cooperation grants (TCG). Thus, TCG comprise free-standing TCG, which are proposed to finance the transfer of technical and managerial skills or of technology; and investment linked TCG, which are required to reinforce the capacity to achieve specific investment projects (current U.S. dollars). Financial development (FD) defines domestic credit to the private sector (% of GDP). All the data are collected from the world development indicators (WDI) online database (Appendix.1). The study covers annual data over the period of 1980-2019 for the KSA economy. The period of the current study is selected on the accessibility of data.

Therefore, table 2 determines the descriptive statistics of these series for the KSA economy. It denotes that all series are normally distributed as exposed by statistics of Jarque-Bera test. Pairwise correlation analysis denotes that EPC, TCG and FD are positively associated with EnvQ. Likewise, TCP and FD are positively associated with EPC. However, the correlation between MT with EnvQ and EPC are negative. Also, the correlation analysis indicates that TCP and FD are negatively linked with MT.

Table 2. Descriptive statistics and correlation matrix.

	lnEnv	**lnEPC**	**lnMT**	**lnTCG**	**lnFD**
Mean	2.731	8.606	3.870	16.512	3.237
Median	2.787	8.637	4.154	16.506	3.292
Max	3.015	9.371	4.425	16.911	4.097
Min	2.351	7.586	2.202	15.992	1.917
SD	.169	.456	.573	.195	.548
Skewness	-0.495	-0.287	-1.007	-0.085	-0.496
Kurtosis	2.328	2.361	3.248	3.294	2.891
Jarque-Bera	2.386	1.230	6.866	0.193	1.659
Probability	0.303	0.540	0.322	0.907	0.436
lnEnv	1				
lnEPC	0.483	1			
lnMT	-0.006	-0.596	1		
lnTCP	0.367	0.146	-0.123	1	
lnFD	0.576	0.971	-0.588	0.235	1

Notes: Max., Min. and SD are maximum, minimum and standard deviation, respectively. Data period is 1980-2019 for Saudi Arabia.

3.2. Model specification

The main purpose of the current study is to investigate the determinants of EnvQ in the case of the KSA economy by taking into account the role played by EPC, technological transfer and FD. The relationship among the level of EnvQ (CO_2 emissions) as endogenous variable with the different exogenous and control variables have long been examined simultaneously (Jayanthakumaran et al., 2012; Wang and Wang, 2018; Kahouli, 2018; Shahbaz et al., 2020). The present study considers the following EnvQ function:

$$EnvQ = f\left(EPC, MT, TCG, FD\right) \tag{1}$$

The econometric model for this study is specified as follows:

$$EnvQ_t = \alpha_0 + \alpha_{1t} EPC_t + \alpha_{.2t} MT_t + \alpha_{3t} TCG_t + \alpha_{4t} FD_t + \varepsilon_t \tag{2}$$

The model transformed to log-linear functional form and stated as below:

$$\ln EnvQ_t = \alpha_0 + \alpha_{1t} \ln EPC_t + \alpha_{.2t} \ln MT_t + \alpha_{3t} \ln TCG_t + \alpha_{4t} \ln FD_t + \varepsilon_t \qquad (3)$$

where EnvQ shows, carbon dioxide emissions from electricity and heat production, total (% of total fuel combustion), EPC is electric power consumption per capita, MT is imported technology measured as computer, communications and other services imports, TCG is Technical cooperation grants; the both variables are used as proxies for technological transfer, FD shows domestic credit to private sector proxy for financial development. α_0, t, and ε are respectively the fixed country effect, the time and the residual term.

4. Econometric methodology

To study the association among EPC, technological transfer, FD and EnvQ for the KSA we propose multi-steps methodology based mainly on ARDL procedure and VECM. The ARDL procedure used to estimate the long run and short run relationship presents several advantages: First, it can be applied without having the same order of integration or to have the same optimal lags for all variables in the system. Second, it is particularly useful for this study because he doesn't require large samples or absence of endogeneity between regressors to obtain an efficient estimator. Third, the ARDL does not demand to have multiple equations because a single reduced-form equation may lead to the same findings. Thus, the ARDL model is expressed as follows:

$$\begin{aligned}\Delta \ln EnvQ_t = {} & \alpha_0 + \sum_{k=1}^{n} \alpha_{1k} \Delta \ln EnvQ_{(t-k)} + \sum_{k=1}^{n} \alpha_{2k} \Delta \ln EPC_{(t-k)} + \sum_{k=1}^{n} \alpha_{3k} \Delta \ln MT_{(t-k)} + \sum_{k=1}^{n} \alpha_{4k} \Delta \ln TCG_{(t-k)} \\ & + \sum_{k=1}^{n} \alpha_{5k} \Delta \ln FD_{(t-k)} + \beta_1 \ln EnvQ_{(t-1)} + \beta_2 \ln EPC_{(t-1)} + \beta_3 \ln MT_{(t-1)} + \beta_4 \ln TCG_{(t-1)} + \beta_5 \ln FD_{(t-1)} + \varepsilon_t\end{aligned} \qquad (4)$$

Δ represents the first difference and ε_1 indicates the residual term. The null hypothesis of no cointegration among the variables is $\beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = 0$.

At the start we will verify the order of integration of the variables by utilizing Augmented Dickey-Fuller (ADF) test of Dickey and Fuller (1981) and Phillips-Perron (PP) test of Phillips and Perron (1988). Once proving integration, the next step will be the choice of appropriate criteria; we will propose Akaike Information Criterion (AIC) for this paper to identify appropriate lag length. The AIC preserved in view to choose the smallest lag length value and to reduce the loss of a degree of freedom (Jayanthakumaran et al., 2012 and Ahmed et al., 2015). Likewise, to capture the dynamic results, an AIC is envisaged more superior and effective as compared to Schwarz Information Criterion (SIC), which delivers more effective and reliable findings. When the lag length is designated, we will examine the cointegration among variables, doing so, we will suggest Johansen cointegration in our study. After confirmation of cointegration among variables, we will try to examine the long-run and short-run relationship. Furthermore, to verify the constancy of the model and to confirm finding for policy-maker, this paper applies robustness tests, i.e., Reset test, ARCH test and LM test. The cumulative sum of recursive residual (CUSUM) and cumulative sum of the square of recursive residual (CUSUMsq) tests will be used to verify the stability of the model to recommend policies for implication. Finally, we will turn to examine the direction of causality among variables. In this context, we will propose the VECM Granger causality approach in order to determine the direction of causality among EPC, MT, TCG and FD. Consequently, the empirical equation of VECM Granger causality approach is modeled as follows:

$$\begin{bmatrix} \ln EnvQ_t \\ \ln EPC_t \\ \ln MT_t \\ \ln TCP_t \\ \ln FD_t \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \\ \alpha_5 \end{bmatrix} + \sum_{k=1}^{n} \begin{bmatrix} \alpha_{11k}\alpha_{12k}\alpha_{13k}\alpha_{14k}\alpha_{15k} \\ \alpha_{12k}\alpha_{22k}\alpha_{23k}\alpha_{24k}\alpha_{25k} \\ \alpha_{13k}\alpha_{23k}\alpha_{33k}\alpha_{34k}\alpha_{35k} \\ \alpha_{14k}\alpha_{24k}\alpha_{34k}\alpha_{44k}\alpha_{45k} \\ \alpha_{15k}\alpha_{25k}\alpha_{35k}\alpha_{45k}\alpha_{55k} \end{bmatrix} * \begin{bmatrix} \ln EnvQ_{t-k} \\ \Delta \ln EPC_{t-k} \\ \Delta \ln MT_{t-k} \\ \Delta \ln TCP_{t-k} \\ \Delta \ln FD_{t-k} \end{bmatrix} + \begin{bmatrix} \gamma_1 \\ \gamma_2 \\ \gamma_3 \\ \gamma_4 \\ \gamma_5 \end{bmatrix} * ECT_{t-1} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \\ \varepsilon_{5t} \end{bmatrix} \quad (5)$$

When the error correction term ECT_{t-1} is statistically significant with a negative sign; it is the indication of long-run causality. Furthermore, we employ Wald test to calculate the short-run causality.

5. Empirical findings and discussion

5.1. Stationary tests

This paper applied the ADF and PP unit root tests on the natural logarithms of the variables in level and difference forms to explore the relationship between, EPC, technological transfer, FD and EnvQ in the KSA. The results described in Table 3 reveal that all the variables of the study are stationary at the first difference, which justifies the application of the ARDL technique.

Table 3. Unit root tests analysis.

Variables	ADF test		PP test		Order of Integration
	Level	First difference	Level	First difference	
lnEnvQ	-2.253 (0.1917)	-7.030 (0.003)*	-2.224 (0.2012)	-7.041 (0.000)*	I(1)
lnEPC	-2.821 (0.064)	-6.234 (0.001)*	-2.738 (0.176)	-6.234 (0.005)*	I(1)
lnMT	-2.012 (0.2805)	-6.291 (0.009)*	-1.879 (0.337)	-7.984 (0.001) *	I(1)
lnTCG	-0.799 (0.807)	-7.047 (0.006)*	-1.338 (0.601)	-13.433 (0.000)*	I(1)
lnFD	0.135 (0.963)	-5.388 (0.000)*	-2.104 (0.243)	-5.066 (0.007)*	I(1)

Note: * indicates the level of significance at 1%.

5.2. ARDL cointegration tests

After proving that all the variables share the same integration properties, we move now to investigate the long-run and short-run coefficients by using the ARDL cointegration method. This technique is established on two main steps. Beginning with the first step, the long-run relationship of Eq. (4) will be clarified by investigating the order of lag. This one will be involved to estimate VAR or VECM models that is attained from unrestricted VAR model and by maximized likelihood ratio (LR) criterion, minimized final prediction error (FPE), AIC, SIC, and Hannan Quinn (HQ) criteria. The results of this stage lead to conserve the optimal lag which is found to be 1, except AIC (Table 4).

Table 4. Lag length selection criteria for cointegration VAR lag order selection criteria.

Lag	LogL	LR	FPE	AIC	SC	HQ
0	30.350	NA	1.75e-07	-1.370	-1.1526	-1.293
1	159.377	216.206[i]	6.41e-10[i]	-6.993	-5.687[i]	-6.532[i]
2	186.050	37.487	6.33e-10	-7.083	-4.689	-6.239
3	214.787	32.620	6.39e-10	-7.285[i]	-3.802	-6.057

[i] Indicates lag order selected by the criterion.

Regarding the output of Johansen cointegration (Johansen, 1988; 1991) he has engendered two statistics, trace statistic and Eigenvalues. The result of trace statistics and Eigenvalues for the KSA assume that there are at least four cointegration relationships that exist among cited variables and the null hypothesis of no cointegration can be rejected. The results of the Johansen test are reported in Table 5.

Table 5. Johansen Cointegration Test.

Hypothesized No. of CE(s)	Eigenvalue	Trace statistic	5% critical value	Prob.[a]
None *	0.553	83.834	69.818	0.002
At most 1 *	0.466	53.191	47.856	0.014
At most 2	0.341	29.309	29.797	0.056
At most 3	0.264	13.450	15.494	0.099
At most 4	0.045	1.788	3.841	0.181

* Trace test indicates 1 co-integrating equations at the 5 % level of significance

[a] indicates MacKinnon–Haug–Michelis (MHM) p values of MacKinnon et al. (1999)

In the same order, we apply the minimization of AIC and SC (the lag length is used to be 1) to find the order of lags. The order of optimal lags is reported in Table 6. For both AIC and SC, guides to choosing the same optimal lags (1,0,0,0,1).

Table 6. Order of optimal lags.

Number of lags	AIC	SIC	Number of lags	AIC	SIC
(1,0,0,0,0)	-1.267	-0.966	(1,1,0,1,0)	-1.282	-0.895
(1,1,0,0,0)	-1.345	-1.000	(1,1,0,0,1)	-1.351	-0.963
(1,0,1,0,0)	-1.309	-0.964	(1,1,1,1,0)	-1.252	-0.821

(1,0,0,1,0)	-1.190	-0.846	(1,1,1,0,1)	-1.335	-0.904
(1,0,0,0,1)	***-1.372***	***-1.027***	(1,1,1,1,1)	-1.251	-0.777
(1,1,1,0,0)	-1.370	-0.984			

Italicized and bold statistics denote the minimized AIC and SIC values.

In the second step, we estimate Eq. (4) to evince the long-run and short-run coefficients based on sample data between 1980 and 2019 for the KSA by applying ARDL technique (Table 7). The empirical results display that the lowest value of the 1-year lag in CO_2 emissions coefficient by 0.220. Furthermore, the results of EPC indicate a long-run and short-run positive effect on CO_2 emissions. More precisely, a 1% increase in EPC will lead towards 3.048% increase in environmental degradation. The result is in line with previous studies of Akpan et al. (2012); Bella et al. (2014); Cetin et al. (2018) and Kahouli (2018) who detected a positive and significant link among energy and CO_2 emissions in the short-run and the long-run.

Likewise, EPC contributes to an important volume of CO_2 emissions in the KSA economy, which requires policymakers to design a policy that decreases EPC through the provision of economic incentives for energy saving. However, the coefficient of MT is negative and significant in the long-run which implies that this variable decelerates environment degradation for the KSA. Precisely, a 1% increase in MT may decrease CO_2 emissions by 0.174%. These results support the finding of Kahouli (2018); Wang et al. (2020) and Zameer et al. (2020) since it shows that MT reduces CO_2 emissions. This is due to the fact that technical progress is able to degrade CO_2 emissions due to government decisions which incite domestic producers to exploit environmentally friendly technologies. Therefore, MT in the shape of computers and communication are environmentally friendly. Otherwise, the modern technology transferred to the KSA promotes environment quality. The Government of the KSA needs to consolidate input in R&D and ICT for higher technological strength which will be favorable for protection of the environment.

In addition, the short-run estimate of CO_2 emissions with respect to TCG is negative and significant at the 10% level. In more details, a 1% increase in TCG may decrease CO_2 emissions by 0.121%. Nevertheless, in the long-run this coefficient is insignificant indicating that TCG has no impact on EnvQ, which suggests that TCG is not helpful to the environment of the KSA, and it does not accompany any contribution in environmental degradation. One probable reason for this insignificance relation is that the KSA has satisfied their need by funding the transfer of technical and managerial skills of technology. Finally, the coefficient of FD is positive and significant at the 10% level. It shows that a 1% increase in FD leads to rise CO_2 emissions by about 0.293%. The results are in line with the findings of Ali et al. (2016); Kahouli (2018); Shahbaz et al. (2020) and Acheampong et al. (2020) who confirm the existence of a significant relationship between FD and EnvQ. The development of the financial sector of the Saudi economy plays a very dynamic role in economic growth which directly affects EPC, and therefore has an environmental degradation effect.

The coefficient of lagged error term i.e. ECM are negative and statistically significant at 5 % level confirmed that the long-run relationship among EPC, technological transfer (MT and TCG), FD and EnvQ exist in the case of the KSA economy. In the same order, we apply numerous diagnostic tests to confirm the stability of the model. The results of these tests are reported in the lower portion of Table 7. It is established that there is no serial correlation and heteroscedasticity in the model according to Breusch-Godfrey serial correlation LM test. Moreover, the value of R2 for the model shows goodness of fit. The F-statistic which measures the joint significance of all regressors in the model is statistically significant at the 1% level. The Durbin-Watson statistic is about two; thus, we can deduce the absence of autocorrelation among residuals (prediction errors) from a regression analysis. Besides, the results of sensitivity analysis of CUSUM and CUSUMsq tests suggest that the model applied in this paper is well proven. The results of both the graphs are exposed in Figs 1 and 2 (Appendix.2.). Both lines plotted within the two straight lines, which bound by 5% level of significance. Otherwise, the plots of both statistics are within the boundaries, which establish that the pollution model does not violate any assumption. Hence, the model is stable and estimated results are trusted and well considered for policy practices.

Table 7. Estimated coefficients from ARDL model.

Dependent variable: ΔlnEnvQ					
Short-run results: ARDL (1, 0, 0, 0, 1)			**Long-run results**		
Regressors	Coefficients	t statistics	Regressors	Coefficients	t statistics
ΔlnEnvQ(-1)	-2.95E-05	-0.027**	lnEPC	1.386	2.914*
ΔlnEPC	0.106	0.097*	lnMT	-0.174	-3.916*
ΔlnMT	-0.019	-0.390*	lnTCG	-0.097	-0.068
ΔlnTCG	-0.121	-1.356***	lnFD	0.293	1.729**
ΔlnFD	0.066	1.384*	Constant	1.161	0.447*
ΔlnFD(-1)	-0.248	-1.699*			
ECM(-1)	-0.301	-2.152*			
Diagnostic test statistics					
LM Test:	1.374				
F-statistics	2.334*				
ARCH test	0.458				
Durbin-Watson	1.638				
R-squared	0.797				
Stability Analysis					
CUSUM	Stable				
CUSUMSQ	Stable				

Note: *, **and *** show significance at 1%, 5% and 10% respectively.

5.3. The VECM Granger causality tests

The existence of cointegration among series approves that there ought to be at least four causal relationships; however, it fails to give its direction. Likewise, the present research investigates the direction causal relationship by applying error-correction models based Granger causality tests. Such knowledge is useful in making suitable environmental, energy, technological and financial policies for sustainable development in the case of the KSA (Fig.1). The results on the direction of the long-run and short-run Granger causality are stated in Table 8. Regarding the long-run causality, all the ECT coefficients are negative and statistically significant proposing bi-directional causal relationships between the variables (except TCG). Otherwise, our results find that there is an indication of four causal relationships. First causal relationships from EPC, MT, TCG and FD to the environment. Second causal relationships from environment, MT, TCG and FD to EPC. Third causal relationships from environment, EPC, TCG and FD to MT. Fourth causal relationships from environment, EPC, MT and TCG to FD. Nevertheless, an exception is shown for the TCG equation, which is negative and not statistically significant. This suggests an absence of long-run causality from the environment, EPC, MT and FD to TCG. This analysis supports the argument that FD improves EnvQ by prompting the firms to implement advanced technology which emits less CO_2 emissions during production and/or consumption. These findings are consistent with Talkudar and Meisner (2001); Shabaz et al. (2013) and Avom et al. (2020) who suggest that ICT affects CO_2 emissions through energy and FD. Besides, EPC is Granger caused by FD is consistent with the view studied by Shabaz and Lean (2012) that the financial sector enables firms to adopt advanced and efficient electric technology during the production and/or consumption.

In the same order, results in Table 8 reveal the evidence of three short-run bidirectional granger causality confirming the presence of so-called feedback hypothesis among EPC and environment; MT and environment; EPC and MT. Besides, three short-run unidirectional causal relationships exist: from FD to EPC, from TCG to MT and finally from environment and TCG to FD. The results imply that MT is suitable in improving EnvQ by reducing CO_2 emissions. Besides, MT facilitates the development of smart public transport modes, the reduction in the EPC of household appliances or even the optimization of the management of lighting, heating and air conditioning in industrial buildings, etc. In the context of the KSA, it is clear that MT slows down EPC which stimulates a higher quality of environment. Our results are consistent with those of Tang and Tan (2013); Kahouli (2018); Zafar et al. (2020) who find a bidirectional causality between EPC and technological transfer. In the same context, FD can lead to increased EPC by encouraging consumers to borrow money to buy expensive items. Which allows cheaper and easier access to financial capital, which can be used on the one hand to develop existing businesses, and on the other hand to launch new projects. Consequently, companies will increase their economic activity and, subsequently, the demand for energy affecting as a result environment quality (Gaies et al., 2019; Acheampong et al., 2020).

Table 8. Results of VECM Granger causality analysis.

	Direction of causality					
	Short run					**Long run**
Variables	ΔlnEnvQ	ΔlnEPC	ΔlnMT	ΔlnTCG	ΔlnFD	ECT_{t-1}
ΔlnEnvQ	-	9.590	3.431	0.502	2.818	-0.016
		(0.003)*	(0.072)***	(0.482)	(0.101)	(-0.745)**
ΔlnEPC	4.293	-	4.064	0.063	10.319	-0.0003
	(0.045)**		(0.051)***	(0.801)	(0.002)*	(-0.0667)*
ΔlnMT	3.128	3.113	-	0.021	0.676	-0.021
	(0.085)***	(0.086)***		(0.885)**	(0.416)	(-0.410)***
ΔlnTCG	0.002	1.297	2.836	-	0.012	-0.139
	(0.962)	(0.262)	(0.100)		(0.91)	(-5.008)
ΔlnFD	2.660	1.100	3.725	8.7E-07	-	-0.041
	(0.111)**	(0.301)	(0.061)***	(0.999)*		(-1.847)**

Note: *, **and *** show significance at 1%, 5% and 10% respectively.

Finally, several policy implications could be derived from this study. First, these results call the policymakers and the government of the KSA for more consideration in the subject of environmental protection, since electric power and FD cause environmental degradation (in the short-run and long-run). Thus, the KSA may impose some pollution control policies such as raising the environmental taxes, positioning restraints on activities source of environmental degradation, promising academic institutions and environmental projects that may explain how to use and apply the methods of environment protection. At this level, policy makers have to promote and consolidate the environment quality, and increase the utilization of cleaner energy sources in order to decrease CO_2 emissions and to develop the FD sector. Second, the technological transfer has improved the environment quality in the KSA. Government willing to reduce EPC has been clear with different implemented legal constraints to use best products in terms of electricity use taking into account technological innovation in this field. This shows that the KSA government is already on the right path in improving the living standard of the nation by implementing environmental friendly projects.

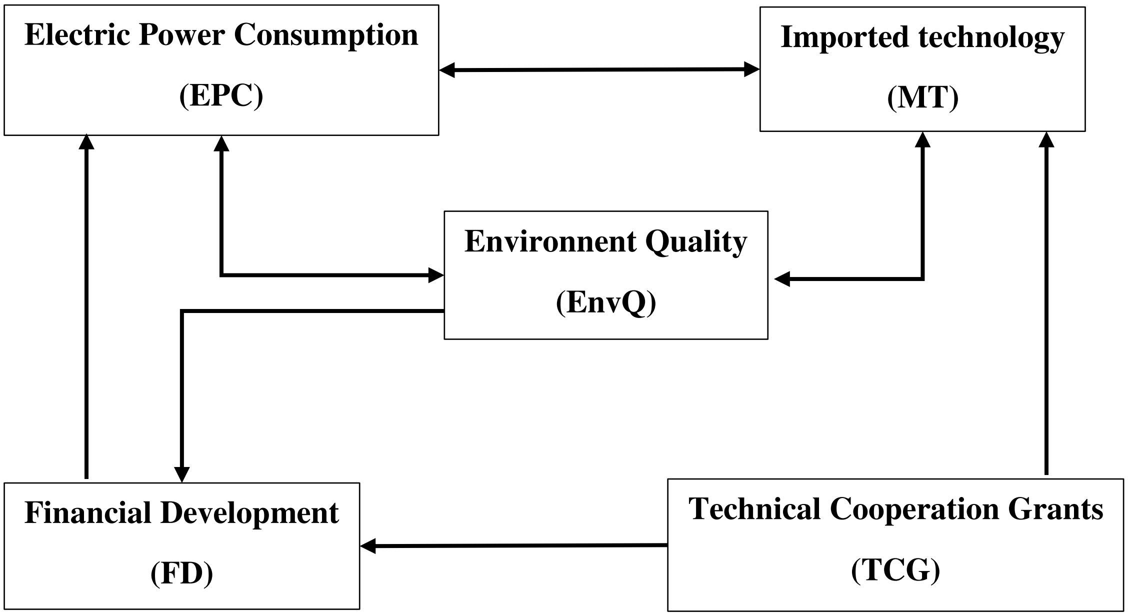

Fig. 1. Pairwise Granger causality results.

6. Conclusion and policy implications

One of the most important strategic objectives of Saudi Arabia 2030 vision is to support efforts and commitment to deal with environmental and economic issues. In this context, this paper examines the effect of relevant technological and economic factors contributing to promote the EnvQ. In the same way, we focus on the effect of the technological transfer (MT and TCG) on CO_2 emissions by integrating several variables such as EPC and FD for the KSA for the period

1980-2019. For the empirical purpose, our intention was to apply multi-steps techniques to investigate the relationships between EPC, technological transfer, FD and EnvQ. Precisely, we have applied the ADF and PP unit root tests in order to verify the order of integration of the underlying data series which is I (1). Likewise, we have studied and verified the existence of cointegration among CO_2 emissions and their determinants by using the ARDL cointegration approach. In the final part of our analysis we have applied the VECM Granger causality to detect the direction of causality. In the light of our empirical results, we have concluded that there is mutual dependence between EPC and CO_2 emissions in the short-run and the long-run. Besides, we have concluded that the development of the financial sector of the KSA plays an important role which is direct and dynamic for the improvement of environment quality. Accordingly, the technological transfer affects negatively the EPC. So, EPC has also proven to be an important factor in increasing CO_2 emissions. It is evident that there is a strong relation among FD, technologic transfer, EPC and environment for the KSA economy.

This result contributes to designing some technological, environmental and financial policies for the KSA. In fact, the policy makers ought to create and to support environmental protection and the green economy. Additionally, the importance of FD in the KSA economy increases the share of the energy sector without harming the environment. We are well aware that the government is moving towards a non-petroleum economic diversification strategy to have more investment flows in the energy domain while encouraging the technological transfer. Therefore, to achieve this, the government is increasingly subsidizing technological projects aimed at reducing energy consumption and thus having a beneficial effect on the environment. In fact, this approach makes it possible to maintain environmental stability and to avoid any negative effects. Likewise, the incorporation of energy efficient technologies into the energy electric segment of the country can be a means of protecting the quality of the overall environment. For this raison, the KSA aims to conserve electricity or use it more efficiently for consumers. Thus, the comprehensive approach to energy policy aims to reduce cost disparities through less subsidies to conventional energy. In this regard, it is necessary to adopt techniques of the cost of energy over several years such as that provided for in their vision 2030. Indeed, policymakers should seek and encourage cleaner sources of energy consumption. They should develop policies for the development of electricity networks in the various cities of the country to achieve energy savings. The application of this type of policy makes it possible to reduce CO_2 emissions. In addition, applying a smart tax system at the same time helps prevent damage to the environment. To conclude, encouraging the technological transfer, facility spillover knowledge, promoting innovation and consolidating R&D activities by financing and support of electric energy sector strategies constitutes the main locomotive to improve the environment quality for the KSA.

Authors' contributions Bassem Kahouli and Benayan Bani Alrasheedy: Conceptualization, Formal analysis, Validation. Nahla Chaaben: Data curation, Software, Writing - original draft. Bassem Kahouli & Rabab Triki: Methodology, Supervision, Writing - review & editing.

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Data availability The data are available upon demand by request to the corresponding author.

Compliance with ethical standards

Competing interests The authors declare that they have no competing interests.

Ethics approval and consent to participate Not applicable.

Consent for publication Not applicable.

Appendix

Appendix.1. A summary of variables.

Variable	Meaning	Unit	Source
EnvQ_t	CO_2 emissions from electricity and heat production.	% of total fuel combustion.	WDI(2019)
EPC_t	Electric power consumption.	kWh per capita.	WDI(2019)
MT_t	Imported technology.	% of commercial service imports.	WDI(2019)
TCG_t	Technical cooperation grants.	Current U.S. dollars.	WDI(2019)
FD_t	Financial development.	% of GDP.	WDI(2019)

WDI (2019): World Development Indicators database, 2019.

Appendix.2.

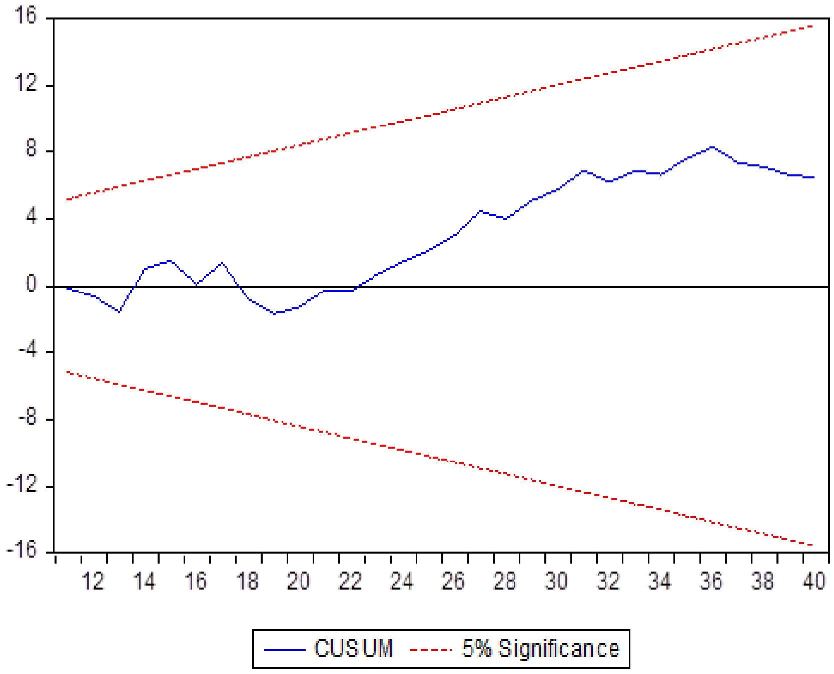

Fig. A.1. Plot of CUSUM.

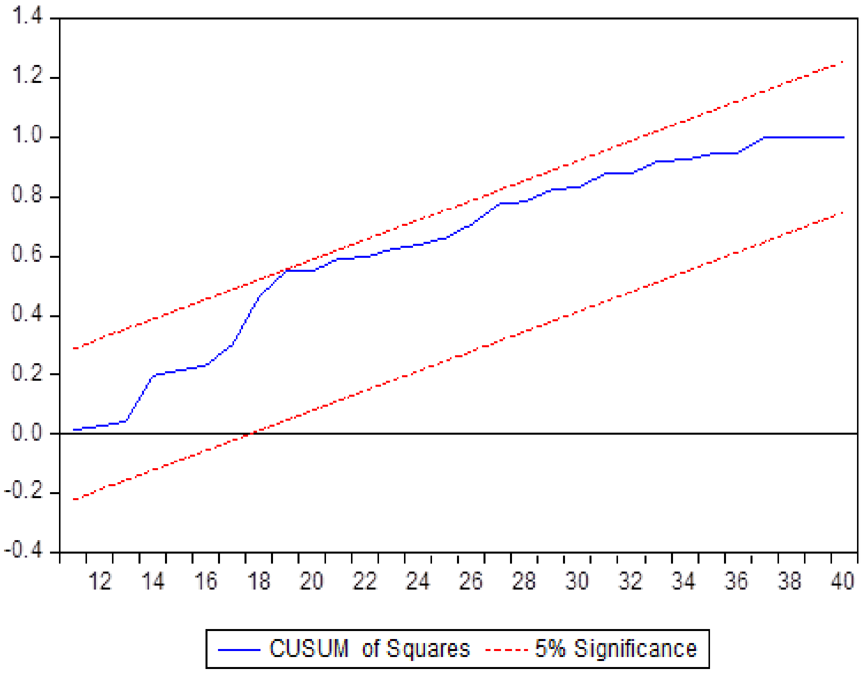

Fig. A.2. Plot of CUSUMsq.

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