An Exploratory Study of the Causality between Internet Use, Innovation, and Economic Growth in Tunisia: An indispensable Case Analysis

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Abstract

In line with the exogenous and endogenous theory coupled with the seminal Schumpeterian contribution, we attempt to investigate the impact of the use of internet and innovation on economic growth in the case of the Tunisian economy. For this purpose, we employ the ARDL bounds testing methodology over the period 1985-2018. In the short-run, our empirical facts outline the absence of a significant effect of innovation on economic growth. Also, our empirical findings reported that the internet stimulates economic growth. However, in the long-run, our empirical findings pointed out the presence of the negative impact of the innovation and the use of internet on economic growth. Moreover, our results show a significant positive impact of the internet and economic growth on innovation in the long-run. Finally, our results show a negative impact of economic growth on the use of the internet. However, the results display a significant positive impact of innovation on the use of the internet. From these perspectives, the Tunisian authorities should take seriously the innovation and the potential of the use of the internet which can help the economy to be modernized, diversified, and robust to create new jobs and to find new markets and new strategic partners, and new opportunities.

Keywords: Innovation; Use of the Internet; Economic Growth; ARDL Bounds testing.

JEL codes: O31, O32, O38, O47,O50.

1. Introduction

With the seminal growth model of Solow (1956) and the prominent contributions of Barro (1991), Barro and Sala-i-Martin (1991, 1992), and Mankiw, Romer, and Weil (1992), the technological progress is seen as a driving force of economic growth, even in exogenous endogenous growth theory (See. Solow, 1956, 1957; Lucas, 1988; Aschauer, 1989; Romer, 1990, 1993; Grossman and Helpman, 1991; Aghion and Howitt, 1992).

Since the beginning of the third millennium that characterized with the incredible spread of the innovation and the use of the internet as a “mantra” of modernizations of societies which greatly caused structural changes in the dynamics of the economy, the well-being of the society, and other aspects. Besides, the use of internet with its great contribution to productivity and economy, trade, and investment (Sichel, 1999, Oliner and Sichel, 2000, Gust and Marquez, 2004, Choi, 2003, Lin, 2015, Lapatinas, 2019), while a negative influence on inflation is recorded by Maurseth (2018). Also, Donou-Adonsou (2019) treats this issue in the case of 45 Sub-Saharan economies, using the GMM estimator over the period from 1993 to 2015. His results reveal that the internet contributes greatly to economic growth if it is combined with good access to education. Lapatinas (2019) uses the data 100 developing and developed economies from 2004 through 2015 using the fixed-effect model and the generalized method of moments (GMM) to examine the effect of the internet on the economic sophistication. The results show a positive effect of the use of the internet on the productive capacities and the economic sophistication for the whole sample.

From the Innovation perspective, with the pioneer works of Schumpeter (1932) and contemporary economist outlooks (Hausman and Johnston, 2014; Coad et al., 2016), the innovation is considered as a fundamental element that considerably boots the different facets of the economy. In terms of economic growth, several studies pointed out the positive contribution of innovation to growth rate of aggregates (Grossman and Helpman, 1994; Grossman, 2009; Fan, 2011; Hudson and Minea, 2013; Agenor and Neanidis, 2015), in terms of competitiveness (Huang, 2011; Galindo and Mendez, 2014; Petrakis et al., 2015). In terms of the financial facet (Aghion and Howitt, 2009; de Serres et al., 2006; Hanley et al., 2011, Corrado et al., 2013; Hsu et al., 2014; Laeven et al., 2015), life standards facet (Tellis, Eisingerich, Chandy & Prabhu, 2008), infrastructural scale (Roig-Tierno, Alcazar & Ribeiro-Navarrete, 2015; Sohag, Begum, Abdullah & Jaafar, 2015), creating jobs (Dachs and Peters, 2014; Kirchhoff, 1994), and foreign openness (Mandel, 2009, Navas, 2015).

From this vision, we are motivated to investigate the conjoint impact of internet and innovation on economic growth for the Tunisian context. To the best of our knowledge, our current work seeks to contribute to the economic theory by investigating the conjoint impact of the use of internet and innovation on economic growth in the case of Tunisia. For this purpose, we use the ARDL bounds testing approach over the period from 1995–2017.

The rest of this paper is as follow: Section 2 outlines an overview of the literature. Section 3 data and materials. Section 4 reflects the discussion of results. Concluding the paper is in Section 5.

2. Literature Survey

2.1. Internet and Economic Growth

Salahuddin et al (2015) estimated the short and long run effects on economic growth using annual time series for Australia for the period 1985 – 2013. ARDL estimates indicate a significant long-run positive relationship between economic growth and internet usage. The short-run relationship between economic growth and internet usage is insignificant. Tripathi and Inani (2016) examined the long-run and short-run relationship between internet usage and economic growth for 42 sub-Saharan African countries by using panel autoregressive distributed lag (ARDL) model for the period 1998 to 2014. The results show that the internet usage has a positive and significant impact on the economic growth in the long-run. However, the internet usage has a negative impact on the economic growth in the short run. Rahimi and Rad (2017) attempted to estimate the short and long run nexus between internet usage and economic growth using 8 developing countries panel data for the period 1990 – 2013. They employed panel cointegration test, pooled mean group regression technique and Dumitrescu–Hurlin causality test. Empirical results indicated that the internet usage cause economic growth. However, economic growth has not any effect on the internet usage. Pradhan et al (2013) investigated the relationship between internet and economic growth in 34 OECD countries during the period 1990 to 2010. They used panel co-integration and panel granger causality. Panel co-integration analysis showed internet and economic growth are cointegrated. Also Panel Granger Causality tests denoted that there is bidirectional causality between internet and economic growth. Choi and Yi (2009) studied the effect of the internet on economic growth in 207 countries from 1991 to 2003. They used Pooled OLS, Panel GMM, random effect and fixed effect. All estimations, found that the use of internet plays a positive and significant role in economic growth. Choi and Yi (2017) examined the effect of internet on economic growth for 105 countries over the period 1994 – 2014 by using panel data analysis (Pooled OLS, Fixed Effects, Random Effects and GMM). Empirical results proved that the internet has a positive impact on economic growth. Saidi and Chebli (2017) examined the causal relationship between internet users and economic growth in high income countries using panel data set from 1990 to 2015. The empirical results of the Panel Vector Error Correction Model (PVECM) showed that there is unidirectional relationship from internet users to economic growth. Jin and Jin (2014) searched the effect of internet education on economic growth by using a cross section of 36 high-income countries. Regression results show that internet has a positive and significant effect on economic growth. Maurseth (2018) reexamined the studied of Choi and Yi (2003) by extending the time period to 2015. He found that the internet has negative and significant effects on economic growth. Noh and Yoo (2008) examined the impacts of Internet adoption and the income inequality on economic growth for 60 countries for the period 1995–2002 has been assembled to test the analytical investigations. The panel estimation shows that the implied effect of Internet adoption on growth is negative for countries with high income inequality.

2.2.Innovation and Economic Growth

Bakari (2019) searched the nexus between innovation and economic growth by taking into consideration the importance of internet in 76 developing and developed countries for the period 1995 – 2016. As empirical technique, Bakari (2019) use Panel ARDL which found that there is positive bidirectional causality between innovation and economic growth in the long run. Also empirical results showed that internet has a positive effect on economic growth and innovation in the long run. Mabrouki (2018) examined the impact of innovation and human capital on economic growth in Tunisia during the period 1970 – 2015. By using VAR model and Granger Causality tests, he found that innovation and human capital cause economic growth. Yang (2006) studied the nexus between innovation and economic growth in Taiwan during the period 1951 – 2001. As an empirical model, he used a VECM model and he found that innovation has a positive impact on economic growth in the long run and in the short run. Galindo and Mendez (2014) analyzed the relationship between entrepreneurship, innovation and economic growth in 13 developed countries [Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Italy, Netherlands, Norway, Sweden, United Kingdom and Spain]. They used a panel data with fixed effect methodology for the period 2002 – 2007. Empirical analysis indicated that innovation and entrepreneurship have positive incidence on economic growth. Sohag et al (2015) investigated the nexus between technological innovation and economic growth in Malaysia for the period 1985 – 2012. By using ARDL bounds testing approach, they found that technological innovation increased economic growth in the long and the short terms. Maradana et al (2019) examined the link between innovation and economic growth for the EEA countries during 1989 – 2014 by deploying a Panel VAR model. They found that there is positive bidirectional causality between innovation and economic growth in the short and long run. Qamruzzaman and Jianguo (2017) studied the impact of financial innovation the financial system in the economic growth of Bangladesh for the period 1980 – 2016. As methods, they applied ARDL Bound testing approach and Error Correction Model to capture the influence of financial innovation on economic growth. Empirical results indicated that financial innovation has positive and statically significant on economic growth both in the short term and long term. Pece et al (2015) examined the nexus between innovation and economic growth in Poland, Czech Republic and Hungary during the period 2000 – 2013. Based on multiple regressions, empirical results indicated that there a positive relationship between innovation and economic growth.

2.3.Innovation and internet

Wu et al (2016) examined the internet's impact on business product innovation. Using data from an original survey of buyer-supplier relationships in China. Empirical results show that collaboration on the internet positively influences innovation in business products. Lee et al (2016) investigated the determinants of technological innovation in the ICT industry in 40 countries from 1999 through 2013. As empirical methodology, they used fixed effects regression models. They found that internet use has a positive impact on ICT innovations. Xu et al (2019) examined the nexus between internet and innovation in different regions from the USA during the period 1995 – 2015. In their study, they applied three types of regression methodologies without instruments, which are OLS regression, Negative Binomial regression and Poisson regression. The empirical results indicate that greater accessibility to the internet has a positive effect on the number of patents.

However, the clear relationship between internet and innovation has not been examined empirically by extant literature. Hence, this study creates contribution to the literature by padding this observed gap.

3. Data Model Specification and Methodology

3.1. Data

We use annual data for the period 1995 – 2017 for the empirical analysis. The data are obtained from the World Development Indicators (WDI, 2018). The variables used in this study include real gross domestic product (2010 constant US $) as proxy to express economic growth, Patent applications (residents) as proxy to express innovation and individuals using the internet (millions of inhabitants) as proxy to express internet. To ensure the stability of the data, we use the logarithmic form for the analysis.

3.2. Econometric model

Previous studies indicate that internet[1] and innovation[2] are major determinants of economic growth. According to our large research in the empirical literature, we found that there is a lack of literature that looks for the nexus between innovation and the usage of internet. There for to estimate the relationship between usage of internet, innovation and economic growth in Tunisia, we employ the econometric model.

The linear relationship between the three variables can be expressed in three equations as follows;

$$\textbf{Model 1: } \mathbf{Ln\,(Y) = \mathit{f}\,(Ln\,(I), Ln\,(N))} \quad \textbf{(1)}$$

$$\textbf{Model 2: } \mathbf{Ln\,(I) = \mathit{f}\,(Ln\,(Y), Ln\,(N))} \quad \textbf{(2)}$$

$$\textbf{Model 3: } \mathbf{Ln\,(N) = \mathit{f}\,(Ln\,(Y), Ln\,(I))} \quad \textbf{(3)}$$

Where Log (Y) is natural logarithm of real gross domestic product (2010 constant US $), Log (I) is natural logarithm of Patent applications (residents), and Log (N) is natural logarithm of Individuals using the Internet (millions of inhabitants)

3.3. Empirical strategy

To examined the nexus between innovation, internet and economic growth in Tunisia, we will use Autoregressive Distributed Lag Model (ARDL Model). In fact, The ARDL model is preferred over other cointegration techniques for several reasons: (i) According to Pesaran et

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[1] See: Choi and Yi (2009), Pradhan et al (2013), Zaghdoudi (2017), Saidi and Mongi (2018), Bakari (2019)

[2] See Ulku, H. (2004), Mabrouki (2018)

al. (2001), this approach is better suited for small sample sizes. However, Johansen's cointegration technique requires a large sample to obtain a valid result (Ghatak and Siddiki, 2001); (ii) This methodology can be applied if the variables used; are all I (1), are all I (0), or are mixed; (iii) The ARDL model makes it possible to study the causality between variables in the long run and in the short run; and (iv) The ARDL Bound test makes it possible to use different lags for the regressors as opposed to the VAR cointegration models where mixed delays for the variables are not allowed (Pesaran et al, 2001).

4. Empirical Analysis

4.1.Stationnary analysis

It is important to examine the order of integration for times series analysis, as the present value of any macro series is often influenced by the lag value. In order to examine the order of integration, we applied Augmented Dickey Fuller (ADF) and Phillips-Perron (PP).

Table 1. Results of order of integration according to ADF test and PP test

Variables	ADF Test		PP Test	
	Constant	Constant and Trend	Constant	Constant and Trend
Log (Y)	2.888117*	0.145015	2.943984*	0.005808
	3.376333**	5.173503***	3.390226**	5.152705***
Log (I)	1.021618	3.435612*	0.753269	3.424483*
	6.706550***	5.276717***	11.96709***	14.61405***
Log (N)	3.366150**	1.269370	3.269701*	1.285729
	3.009888**	4.131725**	3.009888**	4.107328**
***; ** and * denote significances at 1%; 5% and 10% levels respectively				
( ) denotes stationarity in level				
[ ] denotes stationarity in first difference				

Source: Calculations done by the authors based on the EViews 10 software.

The results of the unit root tests affirm that all our variables are stationary at level and at first difference (Table 1). So, ARDL Model can be returned.

4.2.Cointegration analysis

To study the cointegration between variables in our three ARDL Models, we apply the Bounds Test. For the analysis of this last, the econometric rule states that:

- ✓ If the test value F is not more elevated than the bound value I1 in 1%, 2.5%, 5 % and 10% levels, then we can say that there is no cointegration between these variables.
- ✓ If the test value F is more elevated than the bound value I1 in 1%, 2.5%, 5 % and 10% levels, then we can say that there is a cointegration between these variables.

Table 2. Bound test cointegration results (dependent variable: Ln (Y))

Model 1	Ln (Y) = *f* (Ln (I), Ln (N))
Bound test F-statistic	7.719155
Significance	1%
Lower I (0) Bound	5.15
Upper I (1) Bound	6.36
*** Note: Symbolizes significance at the 1% level.	

Source: Calculations done by the authors based on the EViews 10 software.

Table 2 marks that the test value F (7.719155) is more lofty than the bound I1 Bound critical value at 1% level (6.36). Therefore, a cointegration relationship dwells between the variables of the model (1).

Table 3. Bound test cointegration results (dependent variable: Ln (I)).

Model 2	Ln (I) = *f* (Ln (Y), Ln (N))
Bound test F-statistic	8.410819
Significance	1%
Lower I (0) Bound	5.15
Upper I (1) Bound	6.36
*** Note: Symbolizes significance at the 1% level.	

Source: Calculations done by the authors based on the EViews 10 software.

Table 4 points out that the test value F (8.410819) is higher than the bound I1 Bound critical value at 1% level (6.36). Therefore, there is a cointegration relationship between all variables of the model (2).

Table 4. Bound test cointegration results (dependent variable: Ln (N)).

Model 3	Ln (N) = *f* (Ln (Y), Ln (I))
Bound test F-statistic	6.203092
Significance	2,5%
Lower I (0) Bound	4.41
Upper I (1) Bound	5.52
*** Note: Symbolizes significance at the 1% level.	

Source: Calculations done by the authors based on the EViews 10 software.

Table 4 denotes that the test value F (6.203092) is more advance than the bound I1 Bound critical value at 2.5% level (5.52). In this case, we can confirm the existence of a cointegration relationship between variables in the model (3). The results reported in Table (2, 3 and 4) show that for the three Models (1, 2 and 3) there is evidence of cointegration between all variables. In this case, all these models can be estimated by ARDL Model to capture the links of causality in the long term and by WALD test to detect the causality in the short term.

4.3.Causality in the long run

The three long-term equilibrium relationships for the three models are respectively expressed in the following three equations:

Model (1):

LOG(Y) =0.0838 -0.0084*LOG(I) - 0.0037*LOG(N) (4)

Model (1) manifests the following results:

- Innovation LOG(I) has a negative effect on economic growth LOG(Y); a 1% increase in innovation LOG(I) leads to a decrease of 0.0084% of economic growth LOG(Y)
- Internet LOG(N) has a negative effect on economic growth LOG(Y); a 1% increase in internet LOG(N) leads to a decrease of 0.0037% of economic growth LOG(Y)

Model (2):

LOG(I) = -0.2042+0.5948*LOG(Y) + 0.0187*LOG(N) (5)

Model (2) expresses the following results:

- Economic growth LOG(Y) has a positive effect on innovation LOG(I); a 1% increase in economic growth LOG(Y) brings to an increase of 0.5948% of innovation LOG(I)
- Internet LOG(N) has a positive effect on innovation LOG(I); a 1% increase in internet LOG(N) brings to an increase of 0.0187% of innovation LOG(I)

Model (3):

LOG(N) = 15.9254 - 5.2638*LOG(Y) + 0.4557*LOG(I) (6)

Model (3) indicates the following results:

- Economic growth LOG(Y) has a negative effect on internet LOG(N); a 1% increase in economic growth LOG(Y) drives to a decrease of 0.5948% of internet LOG(N)

- Innovation LOG(I) has a positive effect on internet LOG(N); a 1% increase in innovation LOG(I) brings to an increase of 0.4557% of internet LOG(N)

To justify the robustness of the last results, we must examine the significance of the three long-term equilibrium relationships. Econometric rules denote that in the long run, the error correction term (ECT) must has a negative coefficient and a probability less than 5%. In this case, we can say that the equilibrium cointegration equation is significant and that there is really a long term relationship between the variables.

Table 5. Results of ARDL estimation in the long run

ARDL Cointegrating And Long Run Form				
Dependent Variable: DLOG(Y): Model (1)				
Selected Model: ARDL(1, 0, 1)				
Cointegrating Form				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
DLOG(I, 2)	-0.008224	0.012420	-0.662182	0.5167
DLOG(N)	0.006670	0.009552	0.698248	0.4945
ECT	-0.981042***	0.210291	-4.665169	0.0002
Cointeq = DLOG(Y) - (-0.0084*DLOG(I) -0.0037*LOG(N) + 0.0838)				
Dependent Variable: DLOG(I): Model (2)				
Selected Model: ARDL(2, 0, 0)				
Cointegrating Form				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
DLOG(I(-1), 2)	0.430871	0.233859	1.842437	0.0840
DLOG(Y, 2)	1.179203	4.181554	0.282001	0.7816
DLOG(N)	0.036986	0.041079	0.900369	0.3813
ECT	-1.982598***	0.397547	-4.987076	0.0001
Cointeq = DLOG(I) - (0.5948*DLOG(Y) + 0.0187*LOG(N) -0.2042)				
Dependent Variable: LOG(N): Model (3)				
Selected Model: ARDL(4, 3, 3)				
Cointegrating Form				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
DLOG(N(-1))	0.157674	0.215118	0.732964	0.4874
DLOG(N(-2))	0.271397	0.469739	0.577763	0.5815
DLOG(N(-3))	-0.869162	0.422924	-2.055126	0.0789
DLOG(Y, 2)	0.489711	5.803874	0.084377	0.9351
DLOG(Y(-1), 2)	8.804763	7.954266	1.106923	0.3049
DLOG(Y(-2), 2)	-12.976443	7.696342	-1.686053	0.1356
DLOG(I, 2)	0.720037	0.750527	0.959375	0.3693
DLOG(I(-1), 2)	0.272167	0.535884	0.507885	0.6271
DLOG(I(-2), 2)	-0.468906	0.348247	-1.346473	0.2201
ECT	-0.286031***	0.072655	-3.936868	0.0056
Cointeq = LOG(N) - (-5.2638*DLOG(Y) + 0.4557*DLOG(I) + 15.9254)				

Source: Calculations done by the authors based on the EViews 10 software.

Table 5 denotes results of the estimation of long-term equilibrium relationships for the three models 1, 2 and 3; the error correction term (ECT) has a negative coefficient {-1.981042 for Model (1); -1.982598 for Model (2) and -0.286031 for Model (3)} and a probability less than 5% {0.0002 for Model (1); 0.0001 for Model (2) and 0.0056 for Model (3)}.

4.4.Causality in the short run

To determine the causal relationship between innovation, the internet and economic growth in Tunisia, we use the Wald test included in the ARDL model. in fact of the existence of a causal relationship from the independent variable to the dependent variable, the econometric rule consists in that the probability of the Wald test must be less than 5%.

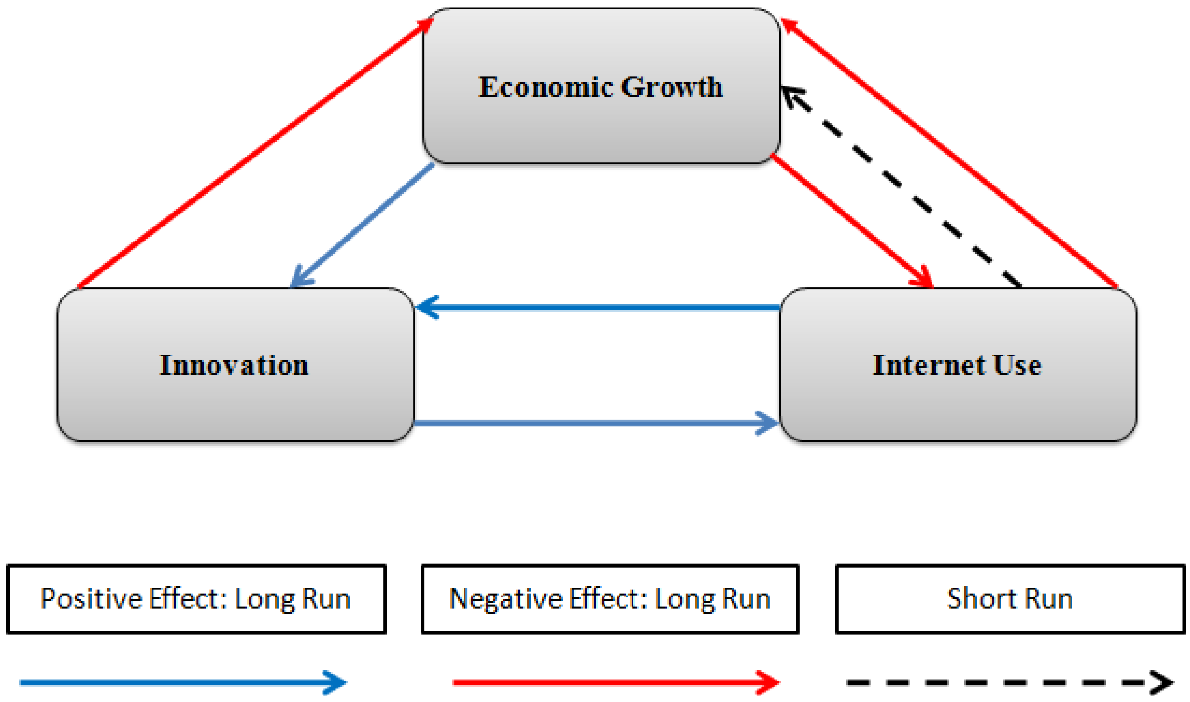
Table 6. Results of ARDL estimation in the short run

WALD Test/Short run in ARDL Model	
Dependent Variable: DLOG(Y)	
	Value
Ln (I)	-0.662182
Ln (N)	4.261029**
Dependent Variable: DLOG(I)	
	Value
Ln (Y)	0.282001
Ln (N)	0.900369
Dependent Variable: DLOG(N)	
	Value
Ln (Y)	1.582815
Ln (I)	1.471310
Note: ***, ** and * denote significances at 1% , 5% and 10% levels, respectively;	

Source: Calculations done by the authors based on the EViews 10 software.

Table 6 presents results of causality in the short run. Wald test indicates that there is no relationship between variables in the three models. We summarize the results of Table 5 and Table 6 in Fig.1

Fig.1: Causality between economic growth, internet use and innovation in the short run and in the long run



4.5.Diagnostic Tests

To confirm the consistency and efficiency of models, a diagnostic test is carried out and the result is reported in Table 7, Table 8 and Table 9. All residual diagnostic tests are clever and contend that our three models {Model (1), Model (2) and Model (3)} are agreeable and well processed (Breusch-Godfrey Serial Correlation LM Test and Heteroskedasticity Testare superior to 5%.).

Table 7. Diagnostic tests of Model (1)

Model: Ln (Y) = *f* (Ln (I), Ln (N))			
Heteroskedasticity Test: Breusch-Pagan-Godfrey			
F-statistic	0.431774	Prob. F(4,17)	0.7838
Obs*R-squared	2.028939	Prob. Chi-Square(4)	0.7304
Scaled explained SS	1.964161	Prob. Chi-Square(4)	0.7424
Heteroskedasticity Test: Harvey			
F-statistic	1.015603	Prob. F(4,17)	0.4271
Obs*R-squared	4.243249	Prob. Chi-Square(4)	0.3741
Scaled explained SS	5.566848	Prob. Chi-Square(4)	0.2339
Heteroskedasticity Test: Glejser			
F-statistic	0.542668	Prob. F(4,17)	0.7066
Obs*R-squared	2.491035	Prob. Chi-Square(4)	0.6462
Scaled explained SS	2.349180	Prob. Chi-Square(4)	0.6718
Heteroskedasticity Test: ARCH			
F-statistic	0.146650	Prob. F(1,19)	0.7060
Obs*R-squared	0.160845	Prob. Chi-Square(1)	0.6884
Breusch-Godfrey Serial Correlation LM Test:			
F-statistic	0.392854	Prob. F(2,15)	0.6819
Obs*R-squared	1.095014	Prob. Chi-Square(2)	0.5784

Source: Calculations done by the authors based on the EViews 10 software.

Table 8. Diagnostic tests of Model (2)

Model: Ln (I) = *f* (Ln (Y), Ln (N))			
Heteroskedasticity Test: Breusch-Pagan-Godfrey			
F-statistic	0.677265	Prob. F(4,16)	0.6176
Obs*R-squared	3.040788	Prob. Chi-Square(4)	0.5510
Scaled explained SS	3.272578	Prob. Chi-Square(4)	0.5133
Heteroskedasticity Test: Harvey			
F-statistic	0.370089	Prob. F(4,16)	0.8265
Obs*R-squared	1.778425	Prob. Chi-Square(4)	0.7764
Scaled explained SS	1.364186	Prob. Chi-Square(4)	0.8504
Heteroskedasticity Test: Glejser			
F-statistic	0.485435	Prob. F(4,16)	0.7463
Obs*R-squared	2.272720	Prob. Chi-Square(4)	0.6857
Scaled explained SS	2.215423	Prob. Chi-Square(4)	0.6962
Heteroskedasticity Test: ARCH			
F-statistic	0.477034	Prob. F(1,18)	0.4986
Obs*R-squared	0.516354	Prob. Chi-Square(1)	0.4724
Breusch-Godfrey Serial Correlation LM Test:			
F-statistic	0.097639	Prob. F(2,14)	0.9076
Obs*R-squared	0.288888	Prob. Chi-Square(2)	0.8655

Source: Calculations done by the authors based on the EViews 10 software.

Table 9. Diagnostic tests of Model (3)

Ln (N) = *f* (Ln (Y), Ln (I))			
Heteroskedasticity Test: Breusch-Pagan-Godfrey			
F-statistic	1.835235	Prob. F(12,7)	0.2145
Obs*R-squared	15.17621	Prob. Chi-Square(12)	0.2319
Scaled explained SS	1.205501	Prob. Chi-Square(12)	1.0000
Heteroskedasticity Test: Harvey			
F-statistic	1.170738	Prob. F(12,7)	0.4338
Obs*R-squared	13.34881	Prob. Chi-Square(12)	0.3442
Scaled explained SS	4.656070	Prob. Chi-Square(12)	0.9685
Heteroskedasticity Test: Glejser			
F-statistic	1.767551	Prob. F(12,7)	0.2296
Obs*R-squared	15.03733	Prob. Chi-Square(12)	0.2394
Scaled explained SS	3.679983	Prob. Chi-Square(12)	0.9885
Heteroskedasticity Test: ARCH			
F-statistic	0.691142	Prob. F(1,17)	0.4173
Obs*R-squared	0.742275	Prob. Chi-Square(1)	0.3889
Breusch-Godfrey Serial Correlation LM Test:			
F-statistic	3.015480	Prob. F(2,5)	0.1383
Obs*R-squared	10.93461	Prob. Chi-Square(2)	0.0042

Source: Calculations done by the authors based on the EViews 10 software.

4.6.Stability Tests

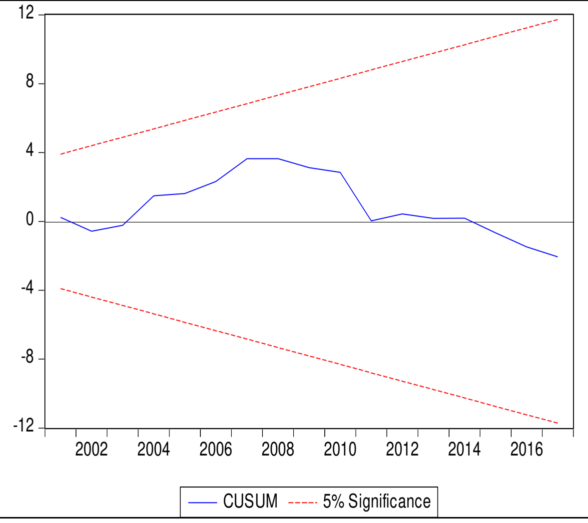
We followed Pesaran and Pesaran (1997) in order to test the stability of the long-run coefficients and the short-run dynamics through the use of cumulative sum of recursive residuals (CUSUM) and the cumulative sum of squares of recursive residuals (CUSUMSQ).

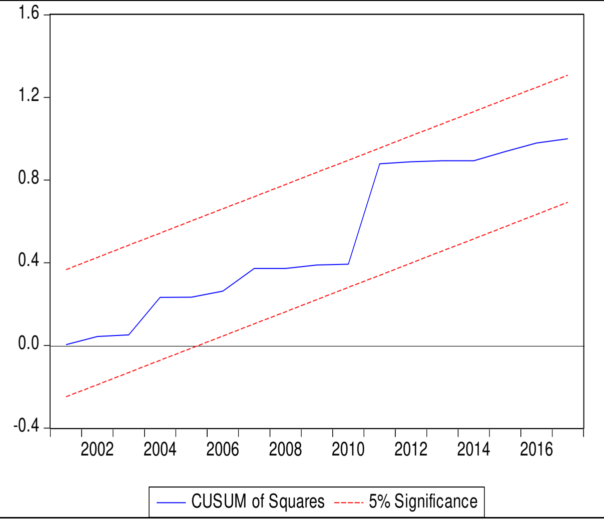
The stability of the model is also confirmed by the cumulative sum of recursive residuals (CUSUM) and cumulative sum of squares of recursive residuals (CUSUM of squares) in Fig.2. The blue lines for both CUSUM and CUSUMSQ lie within the critical bounds and are significance at 5%, which means the model is highly stable over the sample period

Fig.2. Models stability

Ln (Y) = *f* (Ln (I), Ln (N))

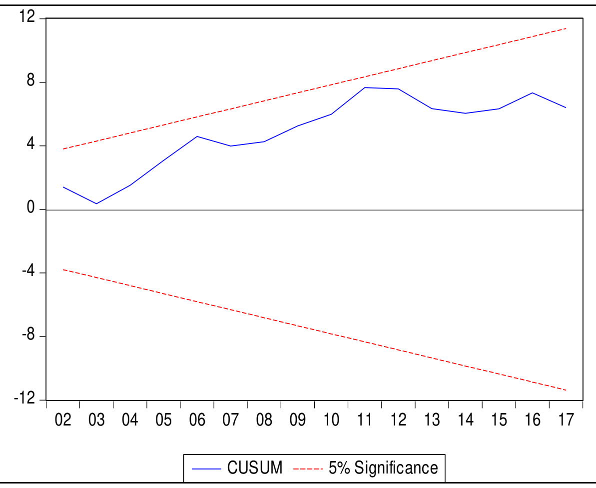
CUSUM Test	CUSUM Square Test

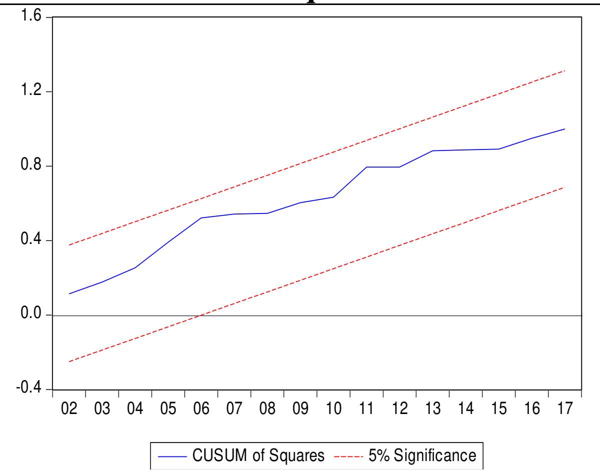




Ln (I) = *f* (Ln (Y), Ln (N))

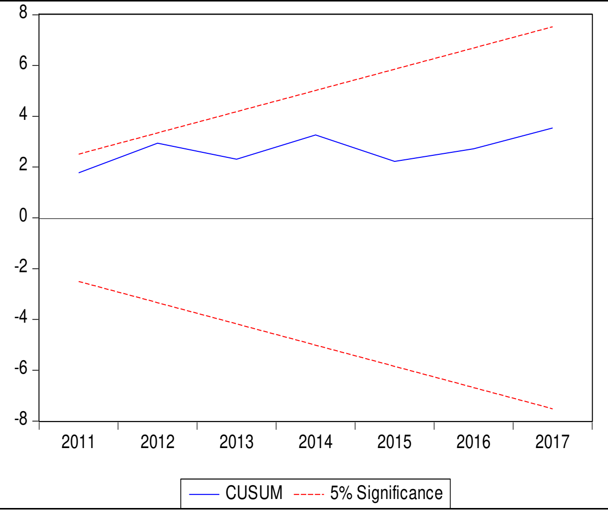
CUSUM Test	CUSUM Square Test

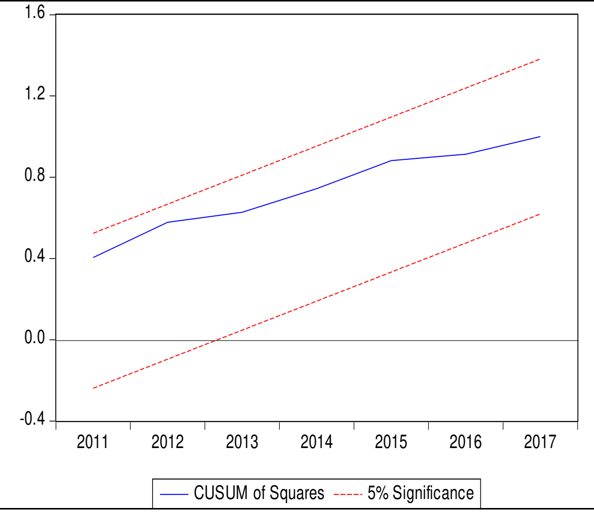




Ln (N) = *f* (Ln (Y), Ln (I))

CUSUM Test	CUSUM Square Test





Source: Calculations done by the authors based on the EViews 10 software.

5. Conclusion

Since the beginning of the 90s Tunisia is the first African and Arabian economy that adopted the innovative technologies and the use of internet in the economy. The current study aims at examining the relationship between innovation, internet use, and economic growth for the Tunisian economy. For this purpose, we use the ARDL bounds testing methodology over the period 1990-2017.

In the short-run, our empirical facts outline the absence of a significant effect of innovation on economic growth. Indeed, the Tunisian economy is based on investment with weak value-added for the economy as a whole. This fact is justified by the absence of the real investment in innovation and R&D that could really play a key role in the transition from a primitive economy essentially based on the exports of raw matter to a modernize economy based on the digitalization and specialized on the high value-added sector of innovation, knowledge, and technology. Also, our empirical findings reported that the internet stimulates economic growth in the short-run. Without any doubt, the internet provides positive externalities which improve economic growth. Furthermore, by minimizing the transactions costs, time, and facilitating communication, productivity improves well, and then the growth path. Moreover, the findings show the absence of any significant impact of economic growth and the use of internet on innovation. This fact implies that in the short-run economic growth and internet couldn't really improve the adoption of the innovation in the production process. Due to the heavy costs in the short-run and the innovation is a strategic issue that needs a strategic vision from the authorities and the establishment of such decisions needs a global perspective based on political, economic, and social structures of Tunisia. Also, the results display the absence of significant impact of economic growth and innovation on the use of internet in the short-run.

However, in the long-run, our empirical findings pointed out the presence of the negative impact of the innovation and the use of internet on economic growth. Indeed, this implies that by reorienting away from the role of internet and innovation from their essential role in the economy towards unproductive behaviors which negatively affects growth. Moreover, our results show a significant positive impact of the internet and economic growth on innovation in the long-run. Indeed, with the presence of the requisite resource to finance the adoption of innovative in the production process, even with the externalities of the internet which help the spread of innovation in the economy. Finally, our results show a negative impact of economic growth on the use of the internet. This implies that the Tunisian economy does not seriously take into consideration the opportunities could be provided by the internet in terms of creating jobs, minimizing the transaction costs this may justify the negative sign. However, the results display a significant positive impact of innovation on the use of the internet. Indeed, this makes in value the high-dependence between the spread of innovation and the use of internet in the economy. From our empirical facts, may we suggest that the Tunisian authorities should take seriously the innovation and the potential of the use of the internet as opportunities. Indeed, this will greatly help the Tunisian economy to be modernized, diversified, and robust to create new jobs, opportunities, and then, to find new markets and new strategic partners.

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