Does the interaction between ICT diffusion and economic growth mitigate CO2 emissions? An ARDL approach

Yahyaoui, Ismahen

20 December 2021

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Abstract

The study tries to evaluate empirically, the impact of ICT and economic growth on CO2 emissions of Tunisia and Morocco for the period 1980-2018, based on the Auto-Regressive Distributive Lag (ARDL) analysis. Findings demonstrate that ICT and economic growth affect positively and significantly the CO2 emissions in the short and long term both in Tunisia and Morocco. However, these direct and negative effects of economic growth and ICT on environmental quality may be decreased by introducing the interaction between ICT and economic growth. So, policy makers should adopt such policies that help to reduce CO2emissions by enhancing the use of ICT for economic growth.

Keywords: Economic growth, ICT, CO2 emissions, Tunisia, Morocco, ARDL.

1. Introduction

In recent decades, climate change has been regarded as the most challenging environmental problem of our time and has attracted the attention of international organizations, policy makers and researchers. In this context, this article aims to examine the relationship between economic growth, ICT and co2 emissions.

From a theoretical point of view, the study of the environmental quality-economic growth relationship began during the second quinquennium of the 1980s. Several studies (World Commission on Environment and Development (1987); Pearce and Warford (1993); Grossman and Krueger (1991)) emphasized the importance of integrating environmental concerns into the planning process in order to ensure sustainable development. Thus, these researchs are the first to use the concept of EKC (the environmental Kuznets curve). These researchs has shown the existence of an inverted U-shaped relationship between economic growth (measured by the increase in per capita income) and certain indicators of environmental quality. In other words, economic growth negatively affects environmental quality by generating more polluting environment. whereas after a certain threshold, further improvement in economic growth contributes to improving the quality of the environment.

Thus, the validity of this assumption depends on the short and long term impact of GDP on CO2 emissions. Then, the EKC is accepted if the coefficient of the income indicator, in the short term, is higher than that of the short term. Moreover, this hypothesis can be tested by integrating the GDP and the square of the GDP in the same model. In this case, the EKC is accepted if the GDP coefficient is positive and the GDP squared coefficient is negative. Thus, environmental degradation may decrease in the long run as incomes become sufficiently high. So, on the face value, one solution to the problem of environmental degradation is to improve economic growth (Stern, 2004a).

In recent decades, information and communication technologies (ICT) have ameliorated the quality of life by becoming one of the important pillars of society. In fact, ICT has an impact on economic prosperity (Levendis and Lee 2013; Asongu 2017), economic growth process (chamyou 2017 ; Murphy and Carmody 2015 ; Penard et al. 2012), and CO2 emissions (Batool et al. 2019; Tsaurai and Chimbo 2019; Asongu 2018; Khan et al. 2018; Ozcan and Apergis 2017). For the role of ICT on ameliorating the impact of economic growth on CO2 emissions, Danish et al. (2018) showed that the interaction between ICT and GDP mitigates the level of pollution.

The study contributes to the specialized literature in at least three ways. First, we examine the short run and the long run relationship between ICT and economic growth using ARDL models, while other previous empirical studies have neglected the panel cointegration and the long-run relationship between these two variables. Second, we study the effect of ICT and environmental quality using four different measures of ICT (mobile subscriptions, fixed broadband subscriptions, fixed-line subscriptions and the Internet), while other previous empirical studies have used only one or two measures of ICT.

In other words, the study allows us to assess the responsibility or the contribution of each measure of ICT in mitigating the CO2 emissions. Finally, our research focuses on the Tunisia and Morocco countries, while after our knowledge; there are only a few studies, especially recent, which are focused on the MENA countries, and which have analyzed the impact of ICT and economic growth on the environmental quality. This study is presented as follows: Following the introduction, section 2presentsa spatial study: a comparative analysis between Tunisia and Morocco. Section 3 presents the data and the model employed in this paper, respectively. Section 4 provides the empirical findings. In Section 5, some concluding remarks and policy recommendations are made.

2. Literature review

Empirically, the impact of ICT and economic growth on the environmental quality has received a great attention by scholars and policy makers during the past few years. However, studies on interaction between ICT and economic growth -environmental quality nexus is still limited. The nexus between technology and CO2 emission is hot issue of debate over the last three decades. In the following section, we present the association between growth and ICT and the environmental quality. Also, we provide a survey on the effect of the interaction between ICT and economic growth on CO2 emissions.

2.1. ICT-CO2 emissions

The first stream of existing literature provides a wide range of studies with mixed results on ICT and environmental quality. For the influence of ICT on CO2 emissions, it differs from a study to another and from a country to another. For instance, AñónHigón et al. (2017) conclude that, in the short run, ICT worsen the environmental quality, however in the long run, it improves through controlling CO2 emissions. In addition, Tamazian et al. (2009) argues that well-developed financial system affect positively the economicgrowth which leads to improving the industrial pollution. Also, Lee and Brahmasrene (2014), using a panel of ASEAN countries,suggest that ICT affect positively and significantlythe economic growth and CO2 emission. Besides, Malmodin and Lunden (2018a) demonstrate that the relationship between ICT usage, carbon emissions and electricity consumption is positive and significant.

However, the second stream conclude the negative relationship between CO2 and ICT. In fact, Ollo-López and Aramendía- Muneta(2012) confirm that ICT helps to decrease CO2 emissions. Besides, Coroama et al. (2012) found that the ICT reduce the CO2 emission, especially the greenhouse gasses (GHGs). Recently, usingthepooled mean grouped (PMG) method, Salahuddin et al. (2016) also revealed that Internet use has a significant long-run relationship with CO2 emission in OECD countries. More recently, Asongu et al. (2019) analyze the nexus between ICT and CO2 emissions in the case of 44 sub-Saharan African countries employing GMM model. Asongu et al. (2019) conclude that ICT has a significant impact on CO2 emission; but, when the square of ICT increases, the level of pollution mitigates. Also, a study done by Salahuddin et al. (2016) confirms that economic growth, financial development, and trade decrease the level of CO2 emission. Similarly, using a panel of 12 Asian countries, Lu (2018) analyzes the impact of ICT, financial development, energy consumption and economic growth on environmental quality. He shows that the use of ICT decreases CO2 emission; but, economic growth, financial development, and energy consumption increase CO2 emission. A study by Hart (2016) also highlighted a negative relationship between ICT and the overall quantity of carbon gas emitted. In addition, Ozcan and Apergis (2017) and Lu (2018) observed that ICT reduced carbon emissions. Malmodin and Lunden (2018b) also provided that ICT led to a decline in carbon emissions in the entertainment and media sectors globally during the period from 2010 to 2015.

However, others reseachs examine the impact of ICT on CO2 emissions and found a non-significant relationship between these variables. In fact, Amri et al. (2019) found a non significant impact of ICT on CO2 emissions in the case of Tunisia over the period 1975-2014. Gelenbe and Caseau (2015) also revealed that the effect of ICT on carbon emissions is mixed. This effect is influenced by the economic sectors involved. Similarly, AlMulali et al. (2015) conclude that ICT measured by the use of internet reduced CO2 emissions in developed nations; while, the effect is insignificant in developing countries. Moreover, Zhang and Liu (2015) conclude that ICT decreases the carbon emissions in the case of China over the period 2000-2010.This effect was found to be insignificant in the western region, while it was greater in the central region as well as in the eastern region.

2.2. CO2emissions-economicgrowth

The second stream of existing literature provides empirical evidence on the relationship between economic growth and environmental quality. The context of economic growth in the region raises the question of the environment in the EKC hypothesis. This hypothesis stipulates that there is a positive relationship between income and CO2 emissions until an income threshold is reached, and after this level the correlation between these two variables becomes negative, i.e. when the income increases, CO2 emissions decrease. There are numerous studies testing for the causal link between carbon emissions and economic growth. In fact, Apergis and Payne (2009), applying FMOL S model and Granger causality test in the case of six Central American countries, confirm the validity of environmental Kuznets curve (EKC). In addition, Pao, Tsai (2011) aimed to explore the causal relationship between energy consumption, CO2 emission, foreign direct investment, and growth in the BRIC countries and Ukraine. The author found that exist a strong positive bi-directional causal relationship between these variables. Similarly, Narayan and Popp (2012) aimed to explore the validity of the Environment Kuznets's Curve (EKC) hypothesis for 93 countries over the period from 1980 to 2004. Narayan and Popp (2012) confirmed the existence of the long-run relationship between energy consumption and real GDP. Dogan and Turkekul (2016) arrived at the same conclusion, using Bounds cointegration model and Granger causality test in the case of USA. However, Katircioglu and Katircioglu (2018) found no evidence to support the existence of the EKC in the case of Turkey. Similarly, in a study for Malaysia over the period 1980–2009, Ozturk and Al-Mulali (2015) failed to confirm the validity of the EKC. Similarly, Al-Mulali et al. (2015) and Shahbaz et al. (2019) confirmed the no validity of the EKC hypothesis over the period 1981–2011 and 1976-2016, respectively. There are a large number of papers empirically examining the issues of the impact of ICT and economic on environmental quality using the tools of econometric analysis.

2.3. Interaction between ICT and GDP-CO2 emissions

Studies on interaction between ICT and economic growth -environmental quality nexus is still limited. In this context, Danish et al. (2018), using an AMG estimations models over the period 1990-2015, conclude that ICT and GDP stimulate the CO2 emissions. However, the interaction between GDP and ICT mitigates the level of pollution in emerging countries. Similarly, Tsaurai and Chimbo (2019) examine the impact of ICT on CO2 emissions using different analysis methods (FMOLS, DOLS, fixed effects and random effects) in emerging economies. He explores that ICT increase carbon emissions. But, he concludes that the interaction between ICT and economic growth, in first hand and the interaction between ICT and financial development, in second hand, reduce the carbon emissions.

3. Spatial study: a comparative analysis between Tunisia and Morocco

The use of Information and Communication Technologies (ICT) is an essential factor for the emergence of the knowledge society and can actively contribute to human development, the improvement of social cohesion and the growth of the national economy.

The International Telecommunication Union (ITU), United Nations Development Agency specialized in information and communication technologies, has measured the development of information and communication technologies (ICTs) in 176 countries. The ITU report is the most reliable data collection and analysis, measuring the overall level of ICT development in the world through 11 indicators divided into three axes: access to ICT(including the number of fixed or mobile phone subscriptions per 100 people or international Internet bandwidth (bits / s) per Internet user), the use of ICT (for example the percentage of people using the Internet or the rate of fixed or mobile broadband subscriptions per 100 people), and finally, ICT skills (including the adult literacy rate or the higher enrollment rate).

At the Maghreb scale, Tunisia comes in second place behind Morocco (89th) in 2017 and ahead of Algeria (106th) and Mauritania (133rd), Libya not being ranked.

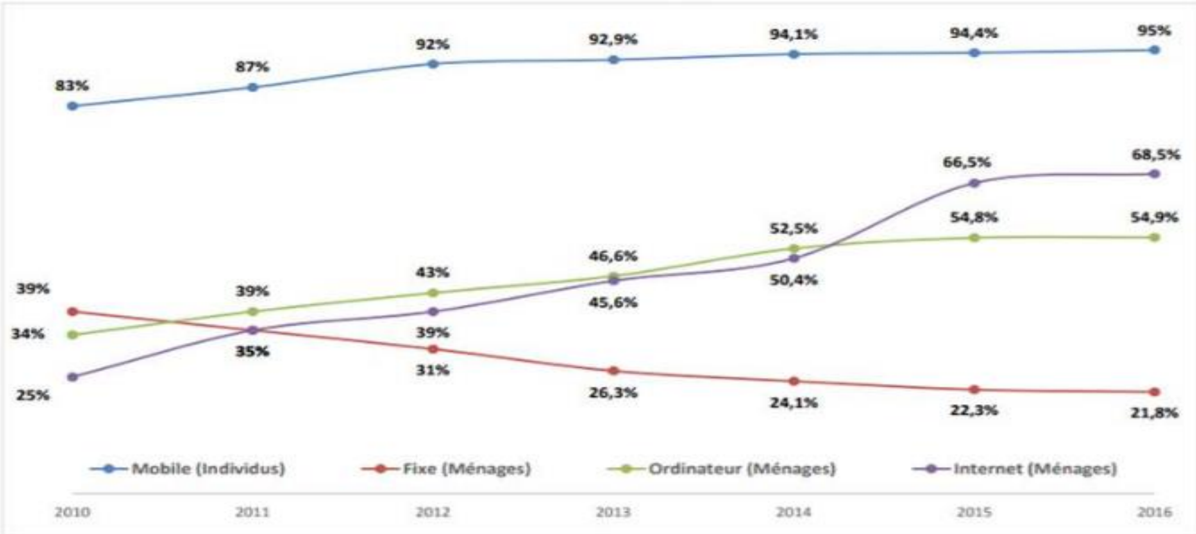
In Morocco, the telecommunications sector has undergone various changes that have contributed to its development: setting up the regulator, introducing new operators to the market, granting licenses ...This brief history presents some key dates of the evolution of the Moroccan telecommunications sector. The Internet pool (fixed and mobile) reached 17.06 million subscribers, bringing the Internet penetration rate to 50.4%. This park recorded an evolution of 17.9% over one year. Outgoing mobile phone traffic slightly exceeded 14 billion minutes in the fourth quarter of 2016.

* Mobile telephony is widespread for almost all households (99.52%) in both urban areas (99.55%) and rural areas (99.49%). 92.9% of individuals equipped with smartphones use it to access the Internet.

* The rate of household equipment in fixed telephony is decreasing during the last six years less than one in four households that is equipped in 2016 (21.8%).

* In 2016, 54.9% of households are equipped with computers / tablets, stagnating compared to 2015. 86.5% of households are equipped with Internet with 77.2% of households in urban areas and 51.3% in a rural area.

Figure 1: Evolution of ICT equipment of individuals and households (2010-2016) in Morocco



Source: ANRT- 2016 Annual ICT Market Survey

Morocco is moving in its development and modernization strategies towards the massive use of information and communication technologies (ICT) as a crucial lever for the creation of economic and social added value.

He added that Morocco has recently created the Digital Development Agency, which is mainly responsible for implementing the State's strategy for the development of the digital economy, piloting, as part of the e-programs. gov, the design and implementation of e-government projects and the development of public services, accompany and assist the relevant authorities and bodies in the design and implementation of large-scale projects in the field of digital economy and disseminate digital tools to citizens.

On the menu of this conclave are a series of lectures, keynotes as well as training sessions able to reinforce the place of this forum as a place of exchange par excellence around a rapidly changing industry, allowing a real immersion in innovative technologies namely "identification system", "new payment channels", "digital banking", "mobile payment", "e-commerce".

Regarding Tunisia, it ranks 99th out of 176 countries in terms of ICT development in 2017, with a score of 4.82 / 10, thus falling by 4 positions compared to 2016, during which it was ranked 95th and had a score of 4.7 / 10. We therefore notice an improvement in the score.

Regarding the 3 aspects of ICT, at the level of access, Tunisia scores 5.11 / 10 compared to a world average of 5.59 / 10. On the side of use, it achieves the score of 4.11 / 10 for a global average of 4.26 / 10. For the "Skills" aspect, Tunisia gets the score of 5.67 / 10 for an average of 5.85 / 10.

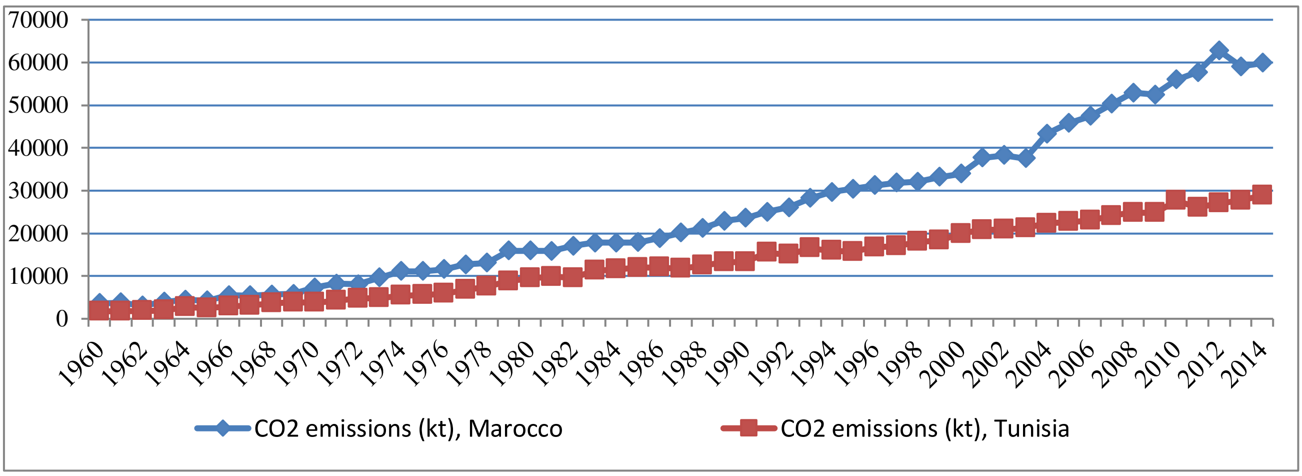
At the level of the Arab countries, Tunisia ranks ninth out of the 19 countries studied, preceded by Kuwait (71st) and Jordan (70th), followed by Morocco, Algeria, Egypt and Libya, which rank respectively 100th, 102nd, 103rd and 115th globally.

Representing 11% of the GDP of Tunisia, a net exporter of computer software and services for TD 1,000 million in 2017, the ICT sector is experiencing a start to the year 2018 on the heels of the momentum.

For example, last February, Arab Soft brought a 365.714 DT contract to the El Ghazela ICT division for the acquisition and implementation of an integrated software package. In the same month, the BITS Informatique company won a contract from the Tunisian Ministry of Social Affairs in the amount of 624,940 DT for the acquisition and implementation of IT solutions for hosting, for itself and the organizations under his supervision. Another SSII was awarded a project to acquire a set of budgeting, auditing and business intelligence solutions for the amount of 250 thousand euros (750 thousand DT).

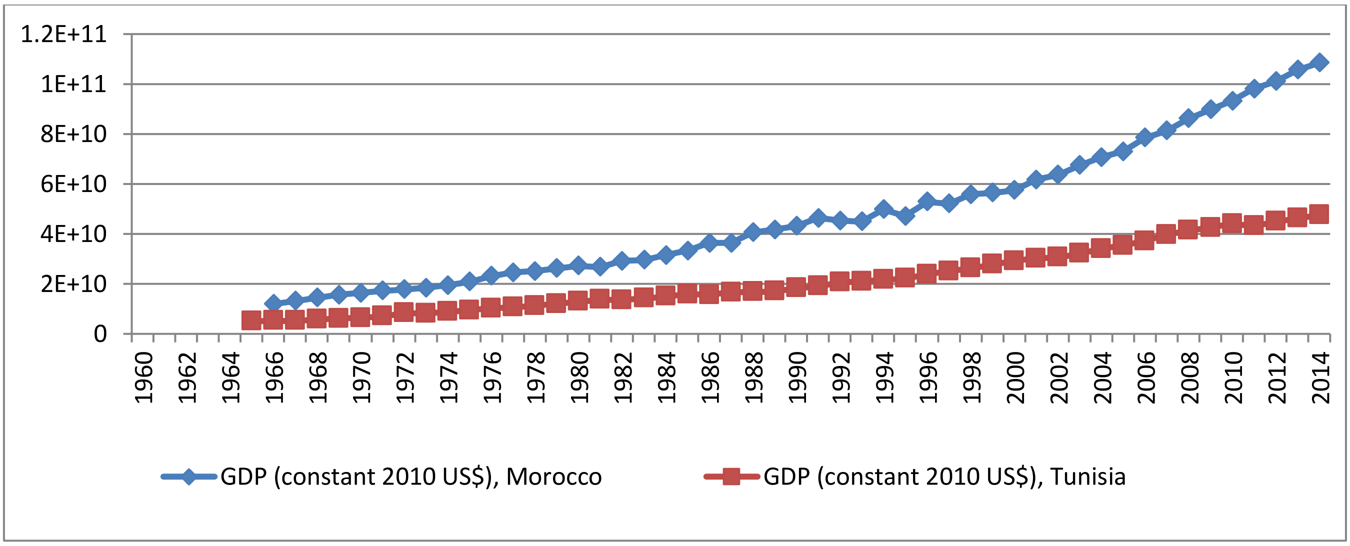
For the CO2 emissions, Tunisia and Morocco are trying to control pollution through its National Environmental Control Agency. However, these countries are dispersed throughout the middle of the 2018 global rankings, with Morocco (54th) leading the regional rankings and Tunisia (58th).

Figure 2: Evolution of CO2 emissions (KT) (2010-2016) in Morocco and Tunisia



Source: Compiled from the World Bank Database

Figure 3: Evolution of CO2 emissions (KT) (2010-2016) in Morocco and Tunisia



Source: Compiled from the World Bank Database

Figures 2–3 show the positive trends of CO2 emissions and GDP in the majority of the years studied in both countries. A positive relationship could be expected from the co-movements of CO2 emissions and GDP.

4. Data, Model, hypotheses and methodology

4.1. Data, Model and hypotheses

The empirical investigation aims to examine the role of ICT in reducing the impact of GDP on CO2 emissions using an ARDL model in the case of Tunisia and Morocco over the period 1980-2018. To do this, we will estimate, on first hand, the direct impact of GDP on CO2 emissions. Therefore, the representation of our models is illustrated:

$$CO2_{it} = \alpha_0 + \alpha_1 GDP_{it} + \alpha 2X_{it} + \varepsilon_{it} \quad (1)$$

$$CO2_{it} = \alpha_0 + \alpha_1 ICT_{it} + \alpha 2X_{it} + \varepsilon_{it} \quad (2)$$

Where i represents each country in the panel and t indicates the time period; **CO2** refers to the CO2 emissions; **GDP** is the GDP per capita growth (annual %); X refers to the explanotary variables that are: **inf** is the Consumer price index (2010 = 100); **find** is the Domestic credit to private sector (% of GDP); **trade** is the sum of Imports of goods and services (% of GDP) and

Exports of goods and services (% of GDP); **invst** is the Gross fixed capital formation (% of GDP).

The expected sign of GDP is positive because economic growth accelerates the level of pollution while the level of CO2 emissions increases (Danish et al. (2018)). The expected sign of $\propto_1$ should be positive. This is essential because with the increase in GDP, people consume more goods; more industries develop so the level of CO2 emissions increases.

On second hand, we will estimate the direct impact of ICT on CO2 emissions. So, in order to study the nature of the relationship between ICT and CO2 emissions, we include ICT proxies, namely, **mcs** is the Mobile cellular subscriptions (per 100 people); **fbs** is the Fixed broadband subscriptions (per 100 people); **fts** Fixed telephone subscriptions (per 100 people); **internet** is the Individuals using the Internet (% of population).

Finally, we study the impact of the interaction between ICT and economic growth on ameliorating the environmental quality. So, we will introduce each time the interaction between GDP and one of measures of ICT. The inclusion of these interactions allows us to examine whether growing economies are increasing the use of ICTs in different sectors to expand economic activities. We then try to examine whether the increased use of ICTs with growing economic growth positively or negatively affects environmental quality.

So, the representation of the models is illustrated:

$$CO2_{it} = \alpha_0 + \alpha_1 GDP_{it} + \alpha_2 ICT_{it} + \alpha_3 GDP * ICT + \alpha_4 X_{it} + \varepsilon_{it} \quad (3)$$

Hypotheses

1. GDP has a destructive effect on environmental quality ; in other words, GDP has a positive impact on CO2 emissions
2. ICT moderates the adverse effect of GDP on environmental quality.

4.2. Methodology

In order to empirically examine whether ICT and economic growth have an effect on CO2 emissions in Morocco and Tunisia, and whether the interaction between ICT and economic growth affects the environmental quality, we applied an Autoregressive Distributed Lag (ARDL) model. This approach is proposed by Pesaran et al. (1996) and subsequently it was modified by Pesaran, Shin and Smith (2001) by introducing the bounds testing approaches. This technique is effective for many reasons. Firstly, it examines the short- and long-term relationships between the different variables that do not have the same order of integration.

Secondly, it can solve the problems associated with autocorrelation and omitted variables. Finally, this approach can be useful for a small sample size application (Pesaran et al., 2001). Before the data are further analyzed, it is necessary to demonstrate the stationarity of all variables. In fact, in order to arrive at robust empirical results, all estimated variables should be non-unit root. In this case, we use four unit root tests Augmented Dickey-Fuller (ADF), Phillips-Perron (PP 1988), Dickey-Fuller GLS (DF-GLS) and KPSS (Kwiatkowski-Phillips-Schmidt-Shin) unit root; whose critical threshold is 5%, and with a null hypothesis (H0) of non stationarity of the variable. The ARDL bounds test is based on the assumption that the variables are I(0) or I(1). So we use the unit root tests in order to make sure that the variables are not I(2) because if variables are I(2), we cannot interpret the values of Fi statistics provided by Pesaran et al. (2001)

The next step is to test the presence of cointegrating relationships among the variables. To do this, we use the bounds test that is mainly based on the joint Fi statistics whose asymptotic distribution is non-standard under the null hypothesis of no cointegration. Once cointegration was established, we estimate the long et short run relationship between ICT, economic growth and CO2 emissions using ARDL model. In order to obtain the dynamic parameters in the short run, we estimate a correction error model associated with long-run estimates (Odhiambo (2009)). The short-run causal effect was represented by Fi statistics on explanatory variables, while the t statistic on the lagged error correction coefficient represents the causal relationship in the long run.

Finally, we examine the causal relationship between ICT, economic growth and CO2 emissions using Toda-Yamamoto Granger causality test. This method is based on the estimation of augmented VAR model (k+dmax) where k is the optimal time lag on the first VAR model and dmax is the maximum integrated order on system's variables (VAR model). To do so, it is necessary, firstly, to determine the integration order for each series using AIC and SC criteria. If the integration order is different we get the maximum (dmax) and we create a VAR model (VAR (k+dmax)) on series levels regardless of integration order that we found. However, if we have the same integration order, we continue on cointegration test using Johansen methodology.

5. Results and discussion

Before applying dynamic ARDL simulations, it is crucial to demonstrate that any series are not I (2).The Unit root test results reported in table 1 indicate that the variables are integrated either in levels or at first differences. So, the estimated results of the unit root tests confirm that dynamic ARDL model can be applied with the used series.

Table 1. Unit Root test results

		ADF		GLS		PP		KPSS	
		Level	First difference	Level	First difference	Level	First difference	Level	First difference
	CO2	0.094	-6.834*	-2.276	-5.942***	-2.678	-6.865***	0.177**	0.053
	Fbs	-3.536*	-3.606**	-3.644**	-3.667***	-1.611	-31.772*	0.698**	0.127
	Find	-1.403	-3.405**	-1.584	-3.503**	-1.811	-3.459*	0.395***	0.262
	Fts	-3.831**	-3.040**	-3.120*	-3.127*	-1.943	-3.032***	0.119*	0.149
Morocco	GDP	-12.406***	-12.284***	-12.707***	-8.862***	-11.629***	-32.107***	0.698*	0.052
	Inf	-4.231**	-4.669***	-1.043	-4.799***	-1.365	-4.652**	0.191**	0.191
	internet	0.276	-4.548***	-1.043	-4.780**	-2.143	-4.569***	0.948***	0.185
	Inv	-2.686	-6.470***	-2.597**	-6.269***	-2.686	-8.123***	1.132***	0.037
	Mcs	-3.927**	-2.686**	-2.486	-2.483*	0.785	-1.903***	1.164***	0.038
	trade	-2.186	-11.489***	-2.323	-6.614*	-2.186	-11.489***	0.404***	0.060
	CO2	-6.834***	-6.770***	-2.276	-6.832***	-2.678	-6.865***	0.224***	0.150
	Fbs	-3.536**	-3.606**	-3.644**	-5.079***	-1.611	-3.540**	1.165***	0.071
	Find	-1.403	-3.405***	-1.584	-3.503**	-1.811	-3.459**	0.162**	0.149
	Fts	-1.826	-3.040***	-3.120*	-3.127*	-1.943	-3.035**	0.121**	0.204
Tunisia	GDP	-12.406***	-12.284***	-12.707***	-8.862***	-11.629***	-32.107***	0.422***	0.034
	Inf	-1.349	-4.669***	-1.043	-4.799***	-1.365	-4.652***	0.240***	0.053
	internet	-2.109	-4.545***	-1.044	-4.780***	-2.143	-4.569**	0.144*	0.196
	Inv	-2.686	-6.470***	-2.597	-6.269***	-2.686	-8.123***	0.246***	0.053
	Mcs	-2.071	-3.927**	-2.486	-2.483**	-1.444	-1.903**	0.144*	0.149
	trade	-2.265	-7.637***	-2.323	-6.614***	-2.186	-11.489***	1.132*	0.039

*, **, and *** denote significant at 10%, 5%, and 1% levels, respectively.

5.1. The direct effect of ICT and GDP on environmental quality

First, we will select the required number of lags of dependent variable and the regressors by applying the information criteria such as Hannan Quinn (1979) Criterion (HQ). Second, the estimation of the model should be carried out based on the number of lags.

According to the results obtained from the AIC and HQ information criteria, one lagis the optimum number to be incorporated in the analysis.

To examine the direct impact of ICT and GDP on CO2 emissions both in Tunisia and Morocco, we will estimate eq (1) and eq (2). So, we will find for each country five regressions. In the four first regressions, we examine the direct effect of ICT on carbon emissions, so, we will introduce each time one of the four measures of ICT in eq (1). In the last regression, we will introduce in eq (2) the variable GDP in order to examine the direct impact of GDP on environmental quality.

To test the cointegration of variables, the ARDL bounds test was used. This test was used to check the long-term relationship among the study series. Table 2 indicates the results of F-statistics which is applied to decide the cointegration. The calculated F-statistics value is greater than the upper bounds value at 10% and 5% level of significance that indicates that cointegration exists among the study variables, both in Tunisia and Morocco for all our models.

This section consists of describing the short-term estimators and presenting an error correction model corresponding to the established cointegration or the long-term equilibriums. The notion CointEq (-1) defines the delayed residue originating from our long term equilibrium equation. The negative sign of its estimated coefficient and its significance for both countries thus confirm the presence of an error correction tool. The coefficient of the cointegration equation explains the order in which the variable CO2 will be mobilized towards the long-term target.

Findings presents in table (4) confirm that ECT is negative and significant which proves that there is a cointegration relationship between the variables of the model. In fact, a negative sign of ECT is essential for a stable error correction mechanism.

With regard to the GDP variable, the short-run results presented in table 4 demonstrate that the coefficient of the present value of the GDP is significant and positive both in Tunisia and Morocco. That is means that economic growth was found to have increased the quantity of CO2 emissions in the case of Tunisia and Morocco. The positive impact of GDP on CO2, emissions can be explained, essentially, by the fact that when economic growth improves, the use of energy increases. So the increase in CO2 emissions is mainly due to the combustion of petroleum, coal and natural gas for energy purposes. Also, the environmental quality can be deteriorated by certain industrial processes namely the production of cement, the manufacture of clothing, the alcohol factories, etc. Then, the increase in the number of economic activities has a detrimental effect on the environmental quality

It is not surprising that there is a strong negative relationship between ICT diffusion and environmental quality, in the short-run model. In fact, the coefficients of each measure of ICT (fbs, fts, internet and mcs) are significant and positive, implying that fts, fbs, internet and mcs negatively influence the Moroccan and Tunisian environmental quality. It is means that the ICT diffusion increases the CO2 emissions. Concerning the variable find, we note that both present and first delayed value have positive effects on carbon emissions of the two countries.

Besides, the findings presented in table 4 confirm, that in the short run, the openness deteriorates the Moroccan and Tunisian environmental quality. In fact, the coefficient of the variable open is positive and significant in all models.

As apparent in Table 4, the coefficient of the variable inf is negative and significant in all models in short run. Therefore, inflation ameliorates the environmental quality in both countries. This negative relationship between carbon emissions and inf can be explained by the fact that when prices increases, energy consumption decreases, as a result the CO2 emissions decreases. Also, we can see that the first delayed value of inf affect negatively the Tunisian CO2 emissions in the first model when we introduce the variable fts as a measure of ICT.

Finally, the variable invst has not an impact on environmental quality in both countries. In fact the coefficient of this variable is insignificant, except, in the case of Tunisia, when we introduce the variable internet in our model invst affects positively and significantly the CO2 emissions. That is means that invst deteriorates the Tunisian environmental quality. The positive relationship between CO2 emissions and invst can be explained, especially, by the fact that invst increases energy consumption that deteriorates the environmental quality.

We can deduce from Table 3 that there is substantial evidence that the variables ICT and GDP have long-run effects on CO2 emissions. Therefore, we will examine the long run direct impact of ICT and GDP on CO2 emissions for both countries. So, we will find for each country five regressions.

Findings presented in table 4 confirm that in the long term all explanatory variables have the same signs of the coefficients in both countries. Similarly the GDP and ICT conserve the same sign in the short run. In other words, in the long run, the economic growth and the ICT diffusion deteriorates the environmental quality in both countries. In fact the coefficient of the variables fbs, fts, internet, mcs and GDP are positives and significants, so when ICT and GDP increase, the CO2 emissions increase.

Table 2.Bounds test results

		fbs		Fts		Internet		mcs		GDP	
		Value	**k**	**Value**	**K**	**Value**	**k**	**Value**	**k**	**Value**	**k**
Morocco	**F-statistic**	13.34639	5	7.957230	5	5.9031****	5	487.8914****	5	3.358989	5
TUnisia	**F-statistic**	234.7109	5	3.554646	5	20.24249	5	8.660912	5	8.524899	5
	Critical Value Bounds										
	Significance	I0 Bound	I1 Bound	I0 Bound	I1 Bound	I0 Bound	I1 Bound	I0 Bound	I1 Bound	I0 Bound	I1 Bound
	10%	2.26	3.35	2.26	3.35	2.26	3.35	2.26	3.35	2.26	3.35
	5%	2.62	3.79	2.62	3.79	2.62	3.79	2.62	3.79	2.62	3.79
	2.5%	2.96	4.18	2.96	4.18	2.96	4.18	2.96	4.18	2.96	4.18
	1%	3.41	4.68	3.41	4.68	3.41	4.68	3.41	4.68	3.41	4.68

Table 3: Short-run estimation and Cointegration Form

	Tunisia					**Morrocco**				
D(fts)	0.105667					0.011213				
	(0.0919)*					(0.0475)**				
D(internet)		0.004530					0.005531			
		(0.0042)***					(0.0485)**			
D(fbs)			0.158974					0.001738		
			(0.0472)**					(0.0569)*		
D(mcs)				0.002628					0.184381	
				(0.0316)**					(0.4265)	
D(GDP)					0.000684*					0.003092
					(0.09496)					(0.0445)**
D(find)	0.002388	-0.002113	-0.011840	0.000783	-0.001869	-0.000413	-0.002521	-0.001001	0.006334	-0.000329
	(0.5233)	(0.2962)	(0.3223)	(0.8444)	(0.7603)	(0.6553)	(0.1600)	(0.4777)	(0.2285)	(0.6871)
D(inf)	-0.002588	0.001626	-0.000621	0.003166	-0.004688	0.004286	0.012687	0.007773	-0.027115	0.007647
	(0.1844)	(0.2852)	(0.8153)	(0.0634)*	(0.0001)***	(0.0141)**	(0.0038)***	(0.0018)***	(0.5197)	(0.0030)***
D(invst)	0.003481	0.020667	-0.053407	0.008117	0.009292	-0.003520	0.000205	0.003657	0.029790	-0.001589
	(0.5665)	(0.0071)***	(0.1752)	(0.2229)	(0.3172)	(0.2429)	(0.9772)	(0.4782)	(0.3270)	(0.6529)
D(trade)	-0.000375	-0.002699	0.008266	-0.000626	0.000796	0.006081	0.008216	0.003704	-0.002034	0.007584
	(0.8776)	(0.1187)	(0.0756)*	(0.8237)	(0.6337)	(0.0186)**	(0.0162)**	(0.1651)	(0.8645)	(0.0006)***
ECT	-0.497580	-0.160037	-2.047010	-0.535696	-0.138107	-0.493236	-1.103459	-0.994354	-0.746526	-0.584643
	(0.0431)**	(0.0087)***	(0.0177)**	(0.0313)**	(0.0993)*	(0.0190)**	(0.0007)***	(0.0325)**	(0.0018)***	(0.0220)**

Table 4: Long Run form

	Tunisia					Morrocco				
FTS	0.014691					0.022735				
	(0.0526)*					(0.0396)**				
INTERNET		0.028306					0.005012			
		(0.0208)**					(0.0110)**			
FBS			0.077662					0.002329		
			(0.0051)***					(0.0123)**		
MCS				0.004905					0.185428	
				(0.0014)***					(0.4076)	
GDP					0.149964**					0.005288**
					(0.04622)					(0.01357)
FIND	0.004799	-0.013206	-0.005784	0.001462	0.027690	-0.000837	-0.002285	-0.001342	0.006370	-0.000563
	(0.4287)	(0.4708)	(0.3024)	(0.8368)	(0.3448)	(0.6819)	(0.1332)	(0.4746)	(0.2397)	(0.7142)
INF	-0.008440	-0.010158	-0.000304	-0.005910	-0.005682	-0.008689	-0.011498	-0.010412	-0.027269	-0.013080
	(0.1041)	(0.2053)	(0.8181)	(0.0016)***	(0.1710)	(0.0000)***	(0.0000)***	(0.0000)***	(0.5299)	(0.0000)***
INVST	0.006996	0.129142	-0.026090	-0.015153	-0.048841	-0.007136	-0.000186	-0.004898	-0.029959	-0.026250
	(0.0752)*	(0.0201)**	(0.0787)*	(0.0968)*	(0.0493)**	(0.0073)***	(0.0772)*	(0.0414)**	(0.0157)**	(0.0497)**
TRADE	0.000754	0.016865	0.004038	0.001169	0.006493	0.012330	0.007445	0.004961	0.002045	0.002851
	(0.8782)	(0.2270)	(0.0415)**	(0.8218)	(0.5486)	(0.0077)***	(0.0152)**	(0.1786)	(0.8627)	(0.5455)
C	0.768715		2.799803	0.936388	0.152608		-0.071089		2.715745	-0.698423
	(0.1669)		(0.0047)***	(0.1395)	(0.9250)		(0.7147)		(0.4284)	(0.0127)**

5.2. The effect of the interaction between ICT and GDP on environmental quality

To examine the role of the interaction between ICT diffusion and economic growth on enhancing the environmental quality, we will estimate in this section eq (3) where we will introduce in our model the variable(GDP*ICT). Because the ICT is measure by four measures (fbs, fts, internet and mcs), so, we will find for each country four regressions.

The ARDL bounds test results are presented in table 5 which demonstrates that the calculated F-statistics value is greater than the upper bounds value at 10% and 5% level of significance that indicates that cointegration exists among the study variables, both in Tunisia and Morocco for all our models.

Finding presented in table 6 resume the ARDL short run relationship between the dependent variable and the explanatory variables. It is necessary to note that the sign of ECTt-1 is as we expected. It is negative and statistically significant. Then, we can conclude that there is a cointegration relationship between the variables of the model.

Findings presented in table 7 show that in the short run, the coefficient of the variable of the interaction between ICT and economic growth is positive and significant. The positive relationship running from the interaction between ICT and economic growth towards carbon emissions signifies that economic growth is a channel through which ICT enhances the environmental quality in both countries. The result collaborates with the findings of Khan et al. (2018) and Danish et al. (2018). So, we can conclude that in the short term, the Moroccan and Tunisian economic growth were found to be a channel through ICT to improve the environmental quality.

Similarly, in the long run, the impact of the interaction between economic growth and technology on CO2 emissions was found to be positive and significant in all models where ICT is measured by fbs, fts, internet and mcs. These results confirm that, also, in long term, economic growth increased ICT's ability to improve the environmental quality in both countries.

Table 5: Bounds test results

		fbs		fts		Internet		mcs		GDP	
		Value	**k**	**Value**	**k**	**Value**	**K**	**Value**	**k**	**Value**	**k**
Morocco	**F-statistic**	12.71726	7	6.405506	7	3.371104	7	2.734757	7	12.71726	7
Tunisia	**F-statistic**	12.97897	7	3.516422	7	28.00420	7	12.82016	7	12.97897	7
	Critical Value Bounds										
	Significance	I0 Bound	I1 Bound	I0 Bound	I1 Bound	I0 Bound	I1 Bound	I0 Bound	I1 Bound	I0 Bound	I1 Bound
	10%	1.7	2.83	1.7	2.83	1.7	2.83	1.7	2.83	1.7	2.83
	5%	1.97	3.18	1.97	3.18	1.97	3.18	1.97	3.18	1.97	3.18
	2.5%	2.22	3.49	2.22	3.49	2.22	3.49	2.22	3.49	2.22	3.49
	1%	2.54	3.91	2.54	3.91	2.54	3.91	2.54	3.91	2.54	3.91

Table 6: Short-run estimation and Cointegration Form

	Tunisia				**Morrocco**			
D(FTS)	0.007626				0.009802			
	(0.0362)**				(0.0405)**			
D(INTERNET)		-0.000788				0.006990		
		(0.0228)**				(0.0427)**		
D(FBS)			0.000959				0.001933	
			(0.0407)**				(0.0909)*	
D(MCS)				0.042950				0.139341
				(0.0125)**				(0.0123)**
D(GDP)	-0.025938	0.016386	-0.015631	-0.094974	-0.000578	0.002642	0.000161	-0.017687
	(0.0565)*	(0.0710)*	(0.0802)*	(0.0828)*	(0.0490)**	(0.0058)***	(0.0824)*	(0.0142)**
D(GDPFTS)	-0.004384				-0.002708			
	(0.0180)**				(0.0923)*			
D(GDPINTERNET)		-0.001025				-0.000331		
		(0.0190)**				(0.0154)**		
D(GDPFBS)			-0.000365				-0.000075	
			(0.0335)**				(0.0552)*	
D(GDPMCS)				-0.025092				-0.007739
				(0.0337)**				(0.0075)***
D(FIND)	0.000552	-0.005342	0.000915	-0.018410	-0.000519	-0.002094	-0.001061	0.005571
	(0.0795)*	(0.0052)***	(0.0782)*	(0.0791)*	(0.0462)**	(0.0878)*	(0.0207)**	(0.0093)***
D(INF)	-0.001820	-0.003863	0.002051	0.001095	0.004997	0.003863	0.007665	-0.021106
	(0.2421)	(0.0513)*	(0.1896)	(0.8309)	(0.0164)**	(0.6818)	(0.0022)***	(0.4839)
D(INVST)	0.008630	0.026646	0.009787	0.017724	0.000159	0.005296	0.003870	0.028430

	(0.1660)	(0.0497)**	(0.0986)*	(0.6759)	(0.9840)	(0.5974)	(0.3379)	(0.2448)
D(TRADE)	0.003438	-0.003735	-0.001877	0.005669	0.005581	0.008942	0.003731	-0.001604
	(0.0855)*	(0.0614)*	(0.4222)	(0.4899)	(0.1024)	(0.0255)**	(0.0524)*	(0.8712)
ECT	-0.174438	-0.279499	-0.377606	-6.957784	-0.504973	-0.958871	-0.724671	-1.061297
	(0.0986)*	(0.0581)*	(0.0832)*	(0.0770)*	(0.0098)***	(0.0111)**	(0.0045)***	(0.0646)*

Table 7: Long-run estimation

	Tunisia				**Morrocco**			
fts	0.043715				0.019411			
	(0.0231)**				(0.4638)			
internet		0.002819				0.007290		
		(0.0996)*				(0.0428)**		
fbs			0.002540				0.002667	
			(0.0674)*				(0.0849)*	
mcs				0.006173				0.131293
				(0.0581)**				(0.0819)*
GDP	-0.148696	-0.058628	-0.041395	-0.013650	-0.001144	0.002755	0.000223	-0.016666
	(0.0205)**	(0.1760)	(0.2187)	(0.0031)***	(0.7554)	(0.5310)	(0.0826)*	(0.0408)**
GDPFTS	-0.025132				-0.005362			
	(0.0921)*				(0.0017)***			
GDPinternet		-0.003666				-0.000345		
		(0.0026)***				(0.0601)*		
GDPfbs			-0.000965				-0.000103	
			(0.0415)**				(0.0653)*	
GDPmcs				-0.003606				-0.007292
				(0.0044)***				(0.7065)
FIND	0.003163	0.019114	0.002424	-0.002646	-0.001027	-0.002184	-0.001464	0.005249
	(0.8657)	(0.5073)	(0.7643)	(0.1101)	(0.7575)	(0.2443)	(0.4920)	(0.1721)
INF	-0.010435	0.013821	0.005431	0.000157	0.009895	0.004029	0.010577	-0.019887
	(0.4436)	(0.2102)	(0.0148)**	(0.8065)	(0.0005)***	(0.6556	(0.0000)***	(0.4713)
INVST	0.049474	-0.095336	0.025918	0.002547	0.000315	0.005524	0.005340	0.026788
	(0.4570)	(0.0865)*	(0.2200)	(0.7252)	(0.9840)	(0.6202)	(0.3290)	(0.1955)
TRADE	0.019707	0.013364	-0.004972	0.000815	0.011052	0.009326	0.005148	-0.001512

	(0.0279)**	(0.0799)*	(0.0471)**	(0.0943)*	(0.0110)**	(0.0412)**	(0.0618)*	(0.0660)*
C	-0.535858	0.666908	1.168986	1.268434	-0.222434	0.289130	-0.028577	2.248929
	(0.0915)*	(0.0268)**	(0.0201)**	(0.0104)**	(0.0683)*	(0.0765)*	(0.0197)**	(0.3187)

Conclusion

Environmental quality is mainly affected by the use of ICT for economic growth.The objective of this study is to examine the relationship between ICT diffusion, economic growth and environmental quality in Morocco and Tunisia from 1980 to 2018. An ARDL simulation model was utilize to describe the short term and the long term impact of ICT and economic growth on environmental quality in both countries. Findings of ARDL simulations model indicate that, in short- and long-term, ICT and economic growth boost Moroccan and Tunisian CO2 emissions. However, the interaction between ICT and economic growth mitigates this effect. In other word, the interaction between ICT and economic growth enhance the environmental quality in both countries. Our results collaborate those of Khan et al. (2018) and Danish et al. (2018) which indicate a negative relationship running from the interaction between the ICT diffusion and economic growth to CO2 emissions

It is recommended that policy makers in Morocco and Tunisia should adopt such policies that help to reduce CO2 emissions by enhancing the use of ICT for economic growth. In fact, the policy makers should adopt modern technology for electrical products and industrial production. Also, policy makers should develop policies that center of attention on energy efficient infrastructure and use clean energy. Similarly, the policy makers should design policies to control the inefficient use of ICTs and originate green ICT projects.

Future papers for investigating the role of ICT in moderating the effect of GDP on CO2 emissions can focus on other large samples, such as MENA countries. Also, future studies may focus on a comparative analysis of the relationship between ICT, GDP and CO2 emissions in developing and developed countries.

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