The Impact of ICT and R&D on Economic Growth in MENA Countries

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Abstract:

This paper explores the impact of Information and Communication Technology (ICT) and Research and Development (R&D) on economic growth in MENA countries. The study uses panel data covering the period from 1990 to 2022 for ten Middle Eastern and North African nations. The objective is to assess how ICT usage and R&D outputs influence economic growth in both the short and long term. Various estimation methods are applied, including DCCE, CS-ARDL, CCEMG, and AMG, following the confirmation of cointegration using the Westerlund test.

The study includes key economic indicators such as GDP per capita, gross fixed capital formation (GFCF), and gross enrollment ratio, along with ICT and R&D variables. The results from the four estimation techniques reveal that ICT and R&D have a negative and statistically insignificant impact on economic growth in both the short and long term. However, robustness checks using CCEMG and AMG indicate a positive and significant effect of GFCF, where a 1% increase in GFCF leads to a 8.23e-08% and 1.10e-07% rise in GDP per capita, respectively. Additionally, the gross enrollment ratio shows no significant effect.

Finally, causality analysis suggests a bidirectional relationship between ICT, R&D, and GDP per capita.

Keywords: ICT, R&D, Economic growth, Dynamic Panel

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I- Introduction:

Different growth theories have come up with many factors that can drive growth. Among them are those that dealt with the positive impact of investing in ICT and R&D. Through its ability to improve productivity, sales volume and employment, as well as economic growth through trading, e-business and e-commerce through various systems of e-business online, for example, conducting transactions with customers online, in addition to innovations that create benefit and are stimulated by scientific research. The continuous development of ICTs also stimulates R&D services and innovations, which in turn stimulate economic growth.

In recent years, the use of ICTs such as mobile phones and the Internet to facilitate seamless production across sectors and improve a large number of economic institutions and international cooperation has recognized macroeconomic performance. Therefore, in order to serve public purposes across economic sectors in developing countries. They proposed the adoption and implementation of ICT economic policies. in addition to attracting competent human capital such as researchers who may create added value and qualify for research that these organizations use to generate additional profits, as the persistent issues they may face may sometimes require radical solutions that only a qualified researcher can provide, which may itself become a commodity or service for sale.

However, studies have been conflicting about the results of this investment, as some have stated that it only provides significant economic gains for developed countries compared to developing countries, especially African countries and Arabic countries. Therefore, in order to refute or confirm these findings, this paper will examine the impact of ICT and R&D in stimulating economic growth in MENA, with data spanning from 1990 to 2022.

At the empirical level, we apply the DCCE and CS-ARDL models than we check the robustness with CCEMG and AMG models in a sample from 1990 to 2022 for 10 North African and Middle East countries, (Algeria, Egypt, Morocco, Tunisia, turkey, Mauritania, Sudan, Saudi Arabic, Bahrain, Jordan) in the Fig(1. ICT and Economic Growth data collected from World Bank database.

Fig(1) . Ten MENA nations map

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I.1problem statement

What is the impact of ICT and R&D on the economic growth in the MENA countries?

I.2. Hypotheses: the main purpose of this paper is to test the following hypothesis:

- There is a log-run relationship between the ICT and R&D and economic growth.

- There is a statistically significal positive effect of the ICT and R&D indicators on the economic growth in the MENA countries in the short term.

- There is a statistically significal positive effect of the ICT and R&D indicators on the economic growth in the MENA countries in the long term.

- There is a bidirectional causality between ICT and R&D indicators and growth economic.

I.3. Research gap

Regardless of the amount of articles and research papers looking at the relationship or impact between ICT or R&D variables on economic growth, few have combined the two. This is what characterizes our study, as most studies are concerned with local economies or the impact of ICT and R&D in advanced economies, but our study is concerned with searching for this impact in North African and Middle Eastern countries, which considered modest in this field. In addition to trying to capture the impact in several estimation methods, which enables us to better understand this impact, second generation tests were used, which ensures more credibility and accuracy of the study's outputs..

1. Data and methodology

1.1. Data and model

This study research about the impact of some ICT and R&D indicators on the economic growth in 10 of **MENA** countries. For this study, we choose the following countries (Algeria, Egypt, Tunisia, Morocco, Bahrain, Jordan, Saudi Arabic, and Soudan, Turkey and Mauritania), over the period 1999-2022. To build the model we take the Individuals using the Internet index. , Mobile cellular subscriptions and the number of Scientific and technical journal articles to express the ICT and R&D, We used gross fixed capital formation and gross enrollment ratio to express physical capital and human capital, respectively. So the model can written like this:

$$GDPi = a + bINTi + cMCSi + dARTi + eGFCFi + gHi \ldots\ldots\ldots [1]$$

1.2. Methodology

1.2.1. CS-ARDL/DCCE model:

We use the CS- ARDL, where its enables us to identify Dynamic Common Correlation Effect (DCCE). This model was introduced by Chudik & Pesaran (2015), according to the principle of Mean Groups (MG) introduced by Pesaran & Smith (1995), the Merged Mean Group (PMG) introduced by Shin & al (1999), the Combined Mean Correlation Effect Group (CCEMG) introduced by Pesaran (2006) the Merged Mean Groups (PMG) presented by Shin & al (1999), the Common Correlated Mean Effect Group (CCEMG) presented by Pesaran (2006). In addition, the Average Improved Mean Groups (AMG) presented by Bond & Eberhardt (2009) and Eberhardt & Teal (2010) (Liton & Tasnim , 2022). This method allows for bias correction in small samples and can applied in the presence of structural breaks. It allows both short-term effects to estimated first and then the long-term coefficients are calculated. According to the following equation (Ameziane & Benyachoub, 2022):

$$RGDP_{i,t} = a_{i,t} + \sum_{j=1}^{p}\left(\delta_{i,j} RGDP_{i,t-j}\right) + \sum_{j=0}^{q}\left(\theta_{i,j} X_{i,t-j}\right) + \sum_{j=0}^{z}\left(Y'_{i,j}\bar{B}_{t-j}\right) + \varepsilon_{it}.[2]$$

With $\bar{B}_{t-j} = (\bar{y}_{i,t-j}, \bar{x}_{i,t-j})$, and Z being the number of lags of the cross-sectional averages to be included. The mean group estimates in the CS-ARDL approach can calculate as follows

$$\varphi_{CS-ARDL,i} = \frac{\sum_{j=0}^{q}\hat{\theta}_{i,j}}{\sum_{j=1}^{p}\hat{\delta}_{i,j}} \ldots\ldots\ldots\ldots\ldots [3]$$

The DCCE model was established by Chudik and Pesaran (2015) by adding a lagged dependent variable as one of the regresses and the lagged cross-sectional averages to the Pesaran (2006) CCE approach. The DCCE model comes with following form:

$$y_{it} = \alpha_i y_{i,t-1} + \gamma_i x_{i,t} + \sum_{i=0}^{PT}\omega_{it}\bar{z}_{i-t} + u_{it} \ldots\ldots\ldots [4]$$

1.2.2. Common Correlated Effect Mean Group (CCEMG) model:

This model was introduced by Pesaran (2006), and improved by Kapetanios & al (2011) The CCEMG estimator includes the averages of the independent and dependent variables as well as unobserved common effects, as shown in Equation [5], which guarantees accurate results regardless of the presence of cross-sectional correlation and regression heterogeneity. By adding a slope that helps eliminate the cross-sectional issue, it

also allows for heterogeneous slope coefficients across group members, which captured by simply taking the average of each country's coefficient according to the following equation (Hoang & Ilhan, 2020):

$$Y_{i,t} = \alpha_{i,t} + \beta_i X_{i,t} + \omega_i \bar{X}_{i,t} + c_i f_t + \varepsilon_{i,t} \ldots\ldots\ldots [5]$$

Where:

Bi: Country-specific slope parameter, ft: The unobserved covariate with the heterogeneity factor

1.2.3. Augmented Mean Group (AMG):

This model developed by Bond & Eberhardt (2009) and Eberhardt & Teal (2010) and is an alternative to CCEMG, which also captures unobserved joint effects in the model [6] .using dynamic joint effect coefficient, furthermore the AMG estimator also measures the group-specific estimator and takes a simple average across the Panel data (Zahid, Bilal, Muhammad, & Rymonda, 2022). The most important feature of the AMG model is that it follows the ordinary least squares first difference of the pooled data through the following equation (Bahar, Taha, & Nursena, 2019)

$$\Delta y_{i,t} = \alpha_i + \beta_i \Delta x_{i,t} + \sum_{t=1}^{T} \gamma_t D_t + c_i f_t + \varepsilon_{i,t} \ldots\ldots\ldots\ldots [6]$$

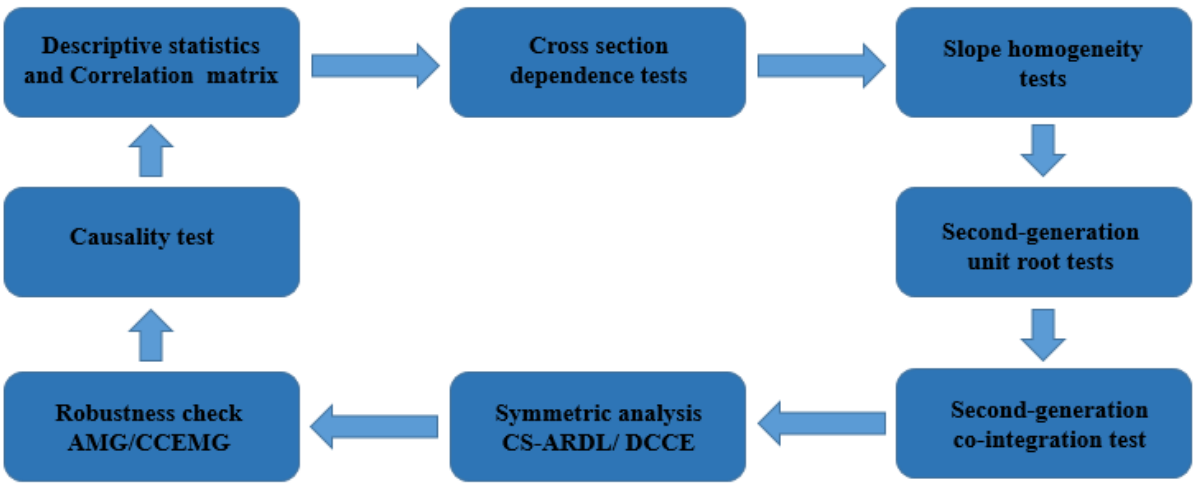
Where: γ represents the dummy time coefficients.

The regression model augmented for the specific group by assigning a coefficient to each observation in the group, and the parameters for the group calculated from the PANEL data according to the following equation

$$AMG = \frac{1}{N} \sum_{i=1}^{N} \tilde{B}_i \ldots\ldots\ldots [7]$$

Estimation steps flowchart introduced in the Fig (2.

Fig (2) .Estimation steps flowchart.



Tab (01) Variable description and data source

Variable	Acronyms	Source
GDP growth	GDP	World Bank database (2025)
Individuals using the Internet	INT	World Bank database (2025)
Mobile cellular subscriptions	MCS	World Bank database (2025)
Scientific and technical journal articles	ART	World Bank database (2025)
Gross fixed capital formation	GFCF	World Bank database (2025)
Gross enrollment ratio	H	World Bank database (2025)

2. Literature Review and theorical framework

2.1. Literature Review:

2.1.1. ICT literature review:

1. (Thomas, 2014) study, which used panel data, sampled 59 countries, including developed, emerging, and developing countries from 1995 to 2010. It confirmed that investment in ICT was more productive in developed countries than in developing ones

2. (Asongu & le Roux, 2017) study, for a sample of 49 South African countries over the period 2002 to 2012. It shows that plans to promote ICT penetration, especially mobile phone and internet penetration will increase inclusive development.

3. (Girijasankar , Tapan , & Pradhan, 2018) study, They used the co-integration method and the Granger causality test on PANEL data for G20 countries during the period 2001-2012 and the results of the study revealed a positive correlation between ICT infrastructure and economic growth.

4. (Usman, ozturk, Hassen, Seyada, & Sana, 2021) which search the ICT on economic performance, the study use 3 south Asian countries over the period 1990 to 2018, to find the effect they employed the ARDL model. The output of this model appear that the ICT significally and positive to the economic growth in the long term in India only.

5. (Kumari & Kumar Singh, 2023) they explore the joint impact of ICT infrastructure, trade openness and the financial development on the economic growth (EG). In a sample of 85 country (27 low –income and 58 high-income economies). The study take a size of 20 years between 2000 and 2019), and used (OLS) and (GMM) and used the fixed effect regression (FER) to. They found that the ICT positively effect the (EG).

2.1.2. R&D literature review:

1. (NAILUL , IZZUDIN, & SITI RIZQI , 2020) study, which examined the impact of R&D spending in nine Asian country (both of the four major Asian countries and the five

ASEAN countries). The study was in the period (1998-2017). They used five different estimation methods, which concluded that R&D spending has a positive and statistically significant impact on economic growth in these nine countries, most of which are developing countries. They also show that the control variables correlated with economic growth. Based on the result of the regression methods, the government needs to increase R&D spending in tax incentives cause of the tax incentives have a positive and significant effect on R&D spending.

2. (Le Thanh & Quan Minh Quoc Binh, 2021) study, which used a unique panel data set of 343 listed companies during the period 2010–2018, they used the fixed effect model and the (2SLS) model, egression results suggest that firms with high R&D outperform those with low R&D in terms of profit, revenue and ROA.

3. (Le Thanh & le nguyen, 2023) study, which investigated the impact of R&D spending on economic growth with a sample of 29 emerging countries between 1996 and 2019, the results show that national R&D spending has positive effects on economic growth both directly and interactively. This evidence has filled the empirical research gap in the relationship between R&D and growth in the case of emerging economies. Finally, while gross capital and education have positive effects on growth, corruption has a detrimental effect on economic growth in these countries.

4. (Agezew, 2024) study, The results show a significant correlation between GDP per capita growth and articles, patents, and technology exports, indicating that these factors are necessary to promote economic growth. However, government spending on R&D has no significant impact on economic growth.

2.1.3. ICT and R&D literature review:

1. (blanco, ji gu, & prieger, 2016) study, they used a panel data of 50 states and the District of Colombia between 1963 and 2007. The model used is the DOLS and PMG, the outcomes of those models, showed that the positive effect of R&D spillovers across states is larger when we consider R&D spillovers across states based on economic similarity of R&D across sectors.

2. (saidi & mongi, 2018) study, they employ panel data during the period 1990 to 2015, the model was used is the VECM model, his outcomes showed that in the short-run there exists a unidirectional relation causality from mobile cellular telephone (MCS) and education to economic growth(EEG). The unidirectional causality it is also from internet users (INT) and mobile cellular telephone and education to research, and the bidirectional causality it is between economic growth (EG) and internet users and between research and development and economic growth, between internet users, education and mobile cellular telephone. In addition, the same causality results also show that there is a bidirectional relationship in the long-run between internet users, education mobile cellular telephone, while there is a unidirectional relationship from internet users to research, and development, economic growth, from mobile cellular telephone to economic growth and research and development in the long-run.

3. (Mahendhiran , pradhan, & mak b, 2020) study, they used a panel data in the OECD countries. The study was in the period 1961 to 2018. The outcomes of the dynamic panel models showed that both R&D and ICT infrastructure development contribute to long-term economic growth in the OECD countries. Moreover, the short-run elasticity's show that complex inter-relationships between these variables exist.

2.2. The theoretical framework

2.2.1. ICT Definition

ICT is the use of information in order to fulfill a human need or purpose, including reference to the use of contemporary devices such as the Internet. However, in an ever-changing world of video phones, mobile computing, blogs, Skype and open source software, perhaps we should no longer just include the Internet, but leave the definition at "contemporary devices...?" (N. Tamilselvan N. , 2019)

The origin of the word technology goes back to the latin language and consists of two syllables: "Techno", which is the art or craft, and the second syllable is "Logia", which are the fields of study and science, so the term "Technology" means:

"the possibility of practical applivation of advanced and modern scientific methods, considering that these scientific methods are often related to new devlopments in processes or production, in addition to the scientific progress affecting the various activities in which they can be used. (رصاع و بوحركات، 2020)

2.2.2.R&D Definition:

R&D according to the OECD-Frascati guide:

Research and experimental development (R&D) encompasses the creative and systematic work undertaken to increase the stock of knowledge - including human, cultural and social knowledge - and to devise new applications of existing knowledge.

There are a set of common features that define R&D activities, even if they are carried out by different organizations. R&D activities may aim to achieve specific or general objectives. R&D always aims to achieve new results, based on original concepts (and their interpretation) or hypotheses. It is highly uncertain about its result (or at least about the amount of time and resources needed to achieve it), is planned and budgeted (even when carried out by individuals), and aims to achieve results that can be freely transferred or traded in the market. For an activity to be an R&D activity, it must meet five basic criteria

The activity must be:

- New
- Innovative
- Uncertain

- Systematic

-Transferable and/or replicable

2.2.3. Definition of Economic Growth

Economic growth generally defined as an increase in the capacity of an economy to produce goods and services, compared from one period to another. This growth, typically measured by the rise in a country's Gross Domestic Product (GDP), which reflects the overall economic activity and health of a nation. (Souad, 2025)

3. Empirical findings and discussion

3.1. Preliminary analysis

Table 2, presents the descriptive statistics of our data. The average of GDP is 5981.217, ranging from 252.6101 to 34454.20, with a positive skewness value (1.856666) and a standard deviation of 7318.296. Moreover, we found that the average of GFCF is 2.10E+15, ranging from 8.12E+08 to 2.73E+16, with a positive skewness value (2.831165) and a standard deviation of 6.28E+15. This confirms that these countries are truly developing countries over the study period. For that, the average of H is 26.57517, ranging from 1.200000 to 128.0000, with a positive skewness value (2.065174) and a standard deviation of 20.95780. Moreover, the average of INT is 24.75228, ranging from 0.00 to 100.0000, with a standard deviation of 29.51343. In addition, the average of MCS is 57.54196, ranging from 0.00 to 212.4529, with a standard deviation of 53.85232. Hence, the average of ART is 3987.551, ranging from 0.000000 to 52657.73 which shows that these countries are keeping pace with technological development and the research and development. Additionally, the standard deviation for MCS is 53.85232, resulting in a coefficient of variation (calculated as (Standard deviation/mean)*100) of 93.59%. For INT, the standard deviation is 29.51343; leading to a coefficient of variation of 119.24%, for ART the standard deviation is 7874.029 leading to a coefficient of variation of 197.47%. These figures indicate a marked shift in the use of information and communications technology and R&D, reflecting the significant strides these countries have made in this direction in recent years. Finally, the Jarque-Bera test outcomes fail to accept the null hypothesis of normality in all the series.

The table 3 presented the correlation matrix results, this matrix Provide a first impression on the nature of the associations between GDP and the other variables. We observe that all coefficients were significant at a 1 % significance level (SL), indicating a significant link between these variables and GDP.. However, the result of VIF confirms no Multicollinearity.

Tab (02) Descriptive statistics.

Variable	GDP	INT	MCS	ART	GFCF	H
Mean	5981.217	24.75228	57.54196	3987.551	2.10E+15	26.57517
Median	3035.540	12.10000	54.96956	940.1450	1.14E+10	21.85000
Max	34454.20	100.0000	212.4529	52657.73	2.73E+16	128.0000
Min	252.6101	0.000000	0.000000	0.000000	8.12E+08	1.200000
Std.Dev	7318.296	29.51343	53.85232	7874.029	6.28E+15	20.95780
Skewness	1.856666	1.078992	0.389110	3.270232	2.831165	2.065174
Kurtosis	5.554295	2.988341	1.927402	14.71692	9.536962	9.042533
Jarque Berra	279.3073	64.03413	24.14627	2475.877	966.0874	736.6148
Prob	0.000000	0.000000	0.000006	0.000000	0.000000	0.000000
Observation	330	330	330	330	330	330

Tab (03) Correlation matrix

Variables	GDP	INT	MCS	ART	GFCF	H	VIF
GDP	1.0000						
INT	0.5846 (0.0000)	1.0000					5.46
MCS	0.5364 (0.0000)	0.8432 (0.0000)	1.0000				3.82
ART	0.2318 (0.0000)	0.4617 (0.0000)	0.3123 (0.0000)	1.0000			4.90
GFCF	0.4651 (0.0000)	0.4475 (0.0000)	0.3834 (0.0000)	0.8577 (0.0000)	1.0000		4.32
H	0.5275 (0.0000)	0.7353 (0.0000)	0.5756 (0.0000)	0.7698 (0.0000)	0.7370 (0.0000)	1.0000	4.70

Significance levels: *** p<0.01, ** p<0.05, * p<0.1. (.) Indicates the p-value.

3.2. Cross section dependence

To test the null hypothesis of no cross sectional dependence (CSD) in the variables, we use 4 different tests that are the (pesaran m. , 2004) (PCD) test and (pesaran m. , 2015) (CD) test, (juodis & reese, 2021) (CD_W) test, (fan, liao, & yao, 2015) (CD_{W+}) and (pesaran & xie, 2021) (CD*) test. The outcomes showed in table 4. Appears the refusal of the null hypothesis in all variables at 1 % SL, however the CD* test accept the null hypothesis in the MCS, ART, GFCF at 1%. However, most tests agree that any shock capable of affecting a certain variable within a nation will transmit to same variable in the other nations in the sample, owing to the interconnectedness among them.

3.3. Slope homogeneity

Prior to conducting the unit root and co-integration scrutiny, it is crucial to accomplish a fundamental test that permits us to consider the authentication of the Slope homogeneity hypothesis within the sample. Accordingly, two tests will be relied upon that are (pesaran & yamagata, 2008) and (blomquist & westerlund, 2013) tests. The outcomes in table 5 Appears clearly the refusal of the null hypothesis of homogeneity in the slope across the MENA nations. Therefore, it is important to consider the heterogeneity constraints on the slope in order to ensure robust results in estimation technics.

Tab (04) CSD issue results

Variables	PCD (pesaran m. , 2004)	CD (pesaran m. , 2015)	CD_w (juodis & reese, 2021)	CD_{w+} (fan, liao, & yao, 2015)	CD* (pesaran & xie, 2021)
GDP	32.58634***	32.59***	-3.09***	215.51***	-4.91***
INT	36.83758***	36.84***	-2.60***	244.51***	-2.02**
MCS	36.34012***	36.34***	-1.95*	241.83	0.78
ART	35.83154***	35.83***	-2.57**	237.79***	1.09
GFCF	26.78724***	30.60***	-3.04***	202.22***	-1.37
H	30.29300***	30.29***	-2.53**	200.68***	2.11**

***, ** and * denotes the significance at 1, 5 and 10 SL respectively

Tab (05) Slope homogeneity tests findings

(pesaran & yamagata, 2008) **test**		
Delta tilde $\hat{\Delta}$		11.361 0.000***
Modified delta tilde $\hat{\Delta}_{adj}$	12.800	0.000***
(blomquist & westerlund, 2013) **test**		
$\hat{\Delta}$ HAC	9.343	0.000***
($\hat{\Delta}$ HAC)adj	10.526	0.000***

***, ** and * significance at 1, 5 and 10 % SL respectively.

3.4. Unit root tests and Co-integration

In the table 6, we find the results of the unit root tests. This table Showed that the variables are first-order integrate I (1). Whereas both of the variable GDP and the explanatory variables (INT, MCS, ART, GFCF, H) are stationary after the first difference.. The study check the existence of a long-term co-evolution of the variables with (Westerlund, 2007), the table 7 presented the results of the test .As a result, and both Gt and Pt statistics show significant values at 5 % SL. As stated by (jahanger, et al., 2023), the rejection of null hypothesis with Gt and Pt statistics provide sufficient evidence to accept the hypothesis of co-integration between series.

Tab (06) Integration order findings

Variables	CIPS test	Pesaran's CADF
GDP	-2.079	-1.393
D(GDP)	-4.572***	-3.355***
INT	-2.536	-2.187
D(INT)	-4.717***	-3.561***
MCS	-2.549	-2.543
D(MCS)	-4.122***	-2.890***
ART	-1.848	-1.731
D(ART)	-3.594***	-1.956*
GFCF	-1.925	-1.585
D(GFCF)	-4.837***	-2.872 ***
H	-2.619	-2.551
D(H)	-4.659***	-3.083***

Tab (07) Co-integration analysis findings

Statistics	Value	Z-value	p-Value	Robust p-value
Gt	-2.749	-1.710	0.044	0.010
Ga	-2.778	3.684	1.000	0.710
Pt	-8.968	-2.470	0.007	0.020
Pa	-1.852	2.457	0.993	0.630

***, **, * signifies the rejection of the null hypothesis at 1, 5 and 10 %, respectively.

3.5. Long run elasticities examination

After we confirm the existence of CSD and Slope homogeneity issue, and found that all the variables are first integrated and the presence of Co-integration, so we need to estimate this relationship between ICT and R&D and GDP per capita.

To find the nature of relation between ICT and R&D, we first estimate the DCCE model. The results in the table 8 showed that there is negative and non-statistically significant effect of ICT and R&D indicators (internet, mobile cellular, and articles), and both of human and physical capital (H and GFCF) are not statistically significant.

The CS-ARDL outcomes in the table 9 are similar to the DCCE, which appear the negative effect of both of ICT indicators and R&D. where the internet and articles not significant but the mobile cellular are significant, the output of MCS elasticity are -22.83% in the 10%.

The output of short-run show a positive and non-statistically significant effect of the INT, and are same with the long run in the MCS indicator which show the elasticity of MCS are -12.3, also the Gross fixed capital effect and the Gross enrollment ratio are not significant.

The error connection parameter (ECT) was negative significant, equal to 0.8548, which meaning that 85.48% of the imbalances in per capita GDP in the long term adjusted in one year.

The diagnostic tests of both models appear that the models as a whole is statistically significant and the R-squared are low. We also note that the problem of serial correlation between sections has addressed; this is what CS test statistics show.

Tab (08) DCCE estimation results

		DCCE		
Variables	Coefficient	Std.error	t-student	Probability
		Long-run		
INT	-9.142293	14.6386	-0.62	0.532
MCS	-0.5323289	4.172199	-0.13	0.898
ART	-2.881139	1.755451	-1.64	0.101
GFCF	6.23e-08	5.19e-08	1.20	0.229
H	-28.65355	19.89023	-1.44	0.150
		Diagnostic tests		
R-Squared		0.35		
F-Statistic		(1.00)		
Residual-based				
CSD		-0.90		
CD statistic		(0.3661)		

Tab (09) CS-ARDL estimation results

		CS-ARDL		
Variables	Coefficient	Std.error	t-student	Probability
		Long-run		
INT	-56.95587	76.9735	-0.74	0.459
MCS	-22.83623	12.61278	-1.81	0.070
ART	-3.97233	4.955431	-0.80	0.423
GFCF	9.07e-08	1.49e-07	0.61	0.544
H	49.26944	41.4845	1.19	0.235
		Short-run		
ECT	-0.8547817	0.1960638	-4.36	0.000
L.INT	37.12586	36.91044	1.01	0.314
L.MCS	-12.30728	7.29548	-1.69	0.092
L.ART	-1.645803	1.619262	-1.02	0.309
L.GFCF	-2.70e-08	5.50e-08	-0.49	0.623
L.H	38.21045	16.68805	2.29	0.022
		Diagnostic tests		
R-Squared		0.27		
F-Statistic		(0.99)		
Residual-based				
CSD		-0.80		
CD statistic		(0.4241)		

3.6. Robustness check

The output of AMG and CCEMG confirm the results of DCCE and CS-ARDL, the results of CCEMG in the table 10 showed the non-statistically significant of internet and confirm the negative effect on the GDP per capita. The same results appear that no ICT and R&D indicators are significant, the CCEMG output show a positive significant effect of gross fixed capital formation, those results elucidate that a 1% increase in GFCF results 8.23e-08%, growth in GDP per capita.

The results of AMG in the same table confirm the results of DCCE, CS-ARDL and CCEMG outputs, which appear the non-effect of ICT and R&D in MENA countries.

These results, although they contradict economic theory, reflect the reality of ICT and R&D in the countries of North Africa and the Middle East. The use of the telephone and the Internet in these countries is mostly personal use, and although this technology has contributed to the digitization of many sectors and the facilitation of many services, it has not been able to be a catalyst for economic growth. According to Solow's paradox, large investments in ICT do not necessarily translate into economic growth at first, as it takes time for businesses and individuals to adjust to these changes. In addition, although the percentage of users has increased dramatically, the quality and speed of connectivity is still poor. As for research and development, its structure in these countries is fragile. These countries suffer from a lack of laboratories and competent researchers. In addition to the focus of these countries on research in the humanities and social sciences, which takes the largest percentage of the number of research, and they also lack publication in highly rated journals, as most research published in national journals, which reduces its readability due to its lack of quality .In addition, the lack of impact means that there is a gap between theoretical research and economic application, in addition to the language barrier. Although many studies have proven the importance of this factor in driving development, such as the study of Barro & Lee (2010). Education considered an important training mechanism to enhance and improve the quality and structure of human capital, as digitally skilled human capital accelerates a country's economic growth. The reason for the immateriality can explained by the weakness of education in developing countries, as most of them aim for the quantity of education rather than the quality

Tab (10) CCEMG and AMG estimates results

		CCEMG		
Variables	Coefficient	Std.error	t-student	Probability
		Long-run		
INT	-0.9294721	8.953907	-0.10	0.917
MCS	0.0778051	4.336378	0.02	0.986
ART	-1.136986	0.7935988	-1.43	0.152
GFCF	8.23e-08	2.31e-08	3.57	0.000
H	-26.98534	16.22095	-1.66	0.096
		AMG		
Variables	Coefficient	Std.error	t-student	Probability
		Long-run		
INT	26.6927	14.53981	1.84	0.066
MCS	4.390545	3.654703	1.20	0.230
ART	-0.8907493	1.784656	-0.50	0.618
GFCF	1.10e-07	2.59e-08	4.23	0.000
H	-21.85238	17.47356	-1.25	0.211

3.7. Causality analysis

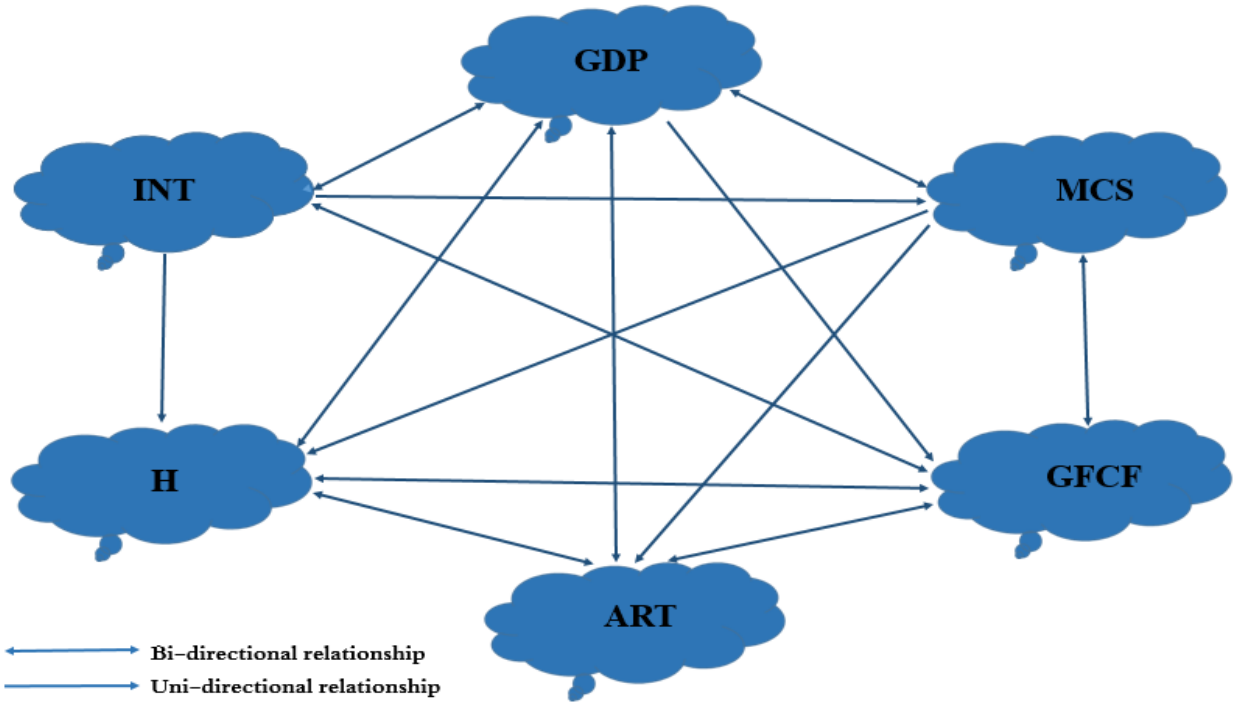
The last and one of the important step of the empirical analysis consists of conducting a causality analysis especially from our ICT and R&D variables to GDP. For this reason, we rely on the modern non-Granger causality test presented by (Juodis, Karavias , & Sarafidis , 2021) panel data causality test. The findings from the ICTs and R&D indicators (INT and MCS, ART) showed that there is a bidirectional relationship between them and the GDP. These results clearly show evidence of the feasibility of using these variables to stimulate and predict future GDP growth, given their significant impact in driving the latter. Nevertheless, the results confirm the presence of a causal connection from the GFCF to GDP, and the absence of a causal connection from GFCF to GDP the same findings showed a bidirectional relationship between Gross enrollment ratio and GDP.

Tab (11) Causal Relationship analysis outcomes

Direction of causality		From					
Variables		GDP	INT	MCS	ART	GFCF	H
To	GDP	/	210.0425***	35.1562***	17.4390***	1.7545	6.4830**
	INT	56.1253***	/	0.2246	2.1497	25.64***	3.9596
	MCS	7.0382**	232.4670***	/	2.8892	8.7922**	10.0966
	ART	12.5652***	3.3814	27.8259***	/	51.75***	18.64***
	GFCF	5.4484*	292.7611***	159.4814***	92.6216***	/	7.7879**
	H	7.4376**	183.2463***	29.2385***	23.6608***	20.59***	/

*** and **,* denote the statistical significance at 1 and 5,10%, respectively.

Fig (3) Causal Relationship associations.



Conclusion:

This study investigates the effects of ICT and R&D on economic growth in MENA countries; we choose ten Middle east and North African countries as a sample size from 1990 to 2022. To test the cross dependence and slope homogeneity the second-generation tests are used, such as (pesaran m. , 2004) (PCD) test and (pesaran m. , 2015) (CD) test, (juodis & reese, 2021) (CD_W) test, (fan, liao, & yao, 2015) (CD_{W+}) and (pesaran & xie, 2021) (CD*) test and (pesaran & yamagata, 2008) , (blomquist & westerlund, 2013) tests, respectively. In addition, this econometric study employed the (CIPS and CADF) unit root tests, the outcomes appear that the data has both of CD and slope heterogeneity issues, and all the variables are first integrated. To test the existence of long-run relationship the (Westerlund, 2007) test used, and confirm that there is a co-integration. The DCCE and CS-ARDL reveal that both of ICT and of R&D indicators (Internet users, Mobile cellular subscriptions and number of Articles) doesn't effect the

growth of GDP per capita which reflect the reality of ICT and R&D on those countries, the output of CCEMG and AMG confirms those results.

These results reveal that the MENA countries, failed to benefit from the growth potential of the ICT and R&D, which can explained by weak infrastructure. As some of these countries still suffer from the lack of high-speed Internet and telecommunications networks, their spread is still limited and their quality is still poor, in addition to the weak integration and interconnection between the ICT sector and the rest of the economic sectors. In addition to widespread corruption in these countries and bureaucratic obstacles that can hinder or delay development by hindering investments and projects needed to develop the necessary ICT infrastructure, research, and development (R&D). In addition to the lack of skills needed in this sector, starting with training that is not in line with the developments in the two fields. In addition, these countries do not allocate large sums of money to invest in the necessary infrastructure, as most of their imports are consumer goods. In addition, they focus on basic research while neglecting applied research that would bring economic benefits, and the technological industry is almost non-existent in these countries.

Finally, (Juodis, Karavias , & Sarafidis , 2021) . The findings from the ICTs and R&D indicators (INT and MCS, ART) showed that there is a bidirectional relationship between them and the GDP.

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