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# The Impact of Information and Communication Technology and Financial Development on Energy Consumption: A Dynamic Heterogeneous Panel Analysis for MENA Countries

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**ABSTRACT**

This study investigates the impact of Information and Communication Technology (ICT) and financial development on energy consumption for a panel of 11 MENA countries, for the period between 1995 and 2014. Unlike previous studies, this study uses principal component analysis to construct an index for ICT. In addition, the dynamic panel data model is estimated using heterogeneous panel estimation technique that accounts for cross-sectional dependence. The results reveal that there is a positive statistical significant relationship between ICT index and energy consumption. However, financial development did not appear to have an impact on energy consumption. We conclude that while ICT use increases energy consumption, financial markets development did not contribute to the increase in energy consumption. Finally, some policy implications relevant to our empirical results are discussed such as the need for policy makers to formulate appropriate and effective energy conservation policies, as well as to encourage the adoption of more energy saving devices that accompany the increase in the use of ICT in the MENA region.

**Keywords:** Information and Communication Technology, Financial Development, Energy Consumption, MENA Countries
**JEL Classifications:** Q43, O13, O16, O33, C21

## 1. INTRODUCTION

Energy plays an important role in promoting modern living standards around the world. As noted by the energy firm Exxon Mobil in its Outlook for Energy (2018), the global energy demand is expected to increase about 25% from 2016 to 2040. In addition, according to International Energy Agency (2017) even though global energy needs are increasing at a slower rate than previous years, energy demand is still expected to grow by 30% between today and 2040. In particular the energy demand in South Asia is growing at a pace twice as China with developing countries in Asia accounting for two-thirds of global energy growth while the rest is mainly coming from the Middle East, Africa and Latin America. These figures are equivalent to adding two countries with the size of China and India to today's world economy (International Energy Agency, 2017). Without energy savings techniques and efficiency improvements, the world's economy global energy demand could nearly double by 2040 (Exxon Mobil, Outlook for Energy, 2018). This increase in energy consumption accompanied with a rise of pollutant emissions will have negative consequences on the global environment such as severe climate changes. In particular, the demand for energy in the middle East and North Africa region is projected to grow strongly by 2040 (Exxon Mobil, Outlook for Energy, 2018). Moreover, with the growing population in this region, the demand for energy is expected to grow further. A report released by Munich headquartered Siemens estimated the power generation capacity to increase by 66% by the year 2030. (Forbes Middle East, 2017). All these figures, highlight the fact that the MENA region will face increasing challenges to implement and design future energy conservation policies. As a result, knowing if ICT and financial development contribute to the increase in energy consumption is essential if energy conservation policies which will support healthier economic growth and development of the MENA region are to be recommended.

The rapid use of Information and Communication Technology (ICT) poses important environmental implications and presents a wide range of impacts on key global indicators such as economic growth and energy consumption. Numerous studies in the literature tackle the ICT-growth nexus, however, few investigate the impact of ICT on energy consumption (Takase and Murota, 2004; Sadorsky, 2012; Ishida, 2015; Saidi et al., 2017). Despite the fact that ICT use is considered as a possible tool to enhance productivity and drive energy efficiency, the impact of ICT on energy consumption is still controversial. Some studies support the view that ICT use reduces greenhouse gas emissions due to increased energy efficiency, while others believe that ICT use will increase energy consumption through the increased use of electricity.

On the other hand, financial development has also been considered as an important factor that affects energy consumption. Zhang (2011) finds that financial development acts as an important driver for carbon emissions increase. The impact of financial development on ICT is still a topic of debate. Some support the idea that an increase in the efficiency of the financial system will provide more capital to energy substitution channels such as renewable energy sector (Dasgupta et al., 2006), which in turns reduces energy consumption. Others believe that an efficient financial system might increase the energy consumption through the creation of new products. The inputs for these products will eventually raise the energy use (Fung, 2009). As argued by Sadorsky (2010), it is ambiguous to determine the effect that financial development has on energy consumption. Hence, financial development should be considered when analyzing factors that might affect energy consumption.

The main objective of this study is to quantitatively analyze the impact of ICT and financial development on energy consumption in a panel of 11 MENA countries for the period between 1995 and 2014, using a heterogeneous panel technique that accounts for cross-sectional dependence among units of the panel. It is important to investigate the relation between these three variables, and if ICT and financial development are found to have a positive impact on energy consumption, MENA countries should consider developing and implementing more effective energy conservation policies.

This study makes several contributions to the literature. First unlike previous studies this is the first study that does not rely on several measures of ICT to analyze its impact on energy consumption. Rather, we use principal component analysis to compute an index for ICT. The index accounts for the three variables used as proxies for ICT in the literature, namely Internet users (per 100 people), the mobile cellular subscriptions (per 100 people), and fixed telephone subscriptions (per 100 people). Second, to the best of our knowledge this is the first paper that addresses the parameter heterogeneity and cross-section dependence issues when assessing the impact of ICT and financial development on energy consumption in the MENA region. Previous studies adopted homogeneous panel data techniques whereby slope coefficients are not allowed to vary across panel units. One major drawback of such techniques is that it ignores cross-sectional dependence among members of the panel, which might yield biased results. This study follows Pesaran (2006) in the use of the common correlated effect mean group estimator (CCEMG). So far, only Topcu and Payne (2017) used the CCEMG to investigate the impact of financial development on energy consumption in high income countries. Third, to the best of our knowledge no published paper incorporates the MENA region as a whole when investigating the impact of two important growth drivers - ICT and financial development- on energy consumption.

The remaining sections of the paper are organized as follows: Section 2 provides the literature review, section 3 presents the data and the empirical model, section 4 includes the methodology and the results and section five concludes and presents some policy implications.

## 2. LITERATURE REVIEW

### 2.1. Financial Development and Energy Consumption Nexus

The literature presents a wide range of studies that tackle the relationship between financial development and energy consumption (see studies of Al-mulali et al., 2015; Rafindadi and Ozturk, 2016; Rafindadi and Ozturk, 2017; Sbia et al., 2017). These studies that cover a large number of countries, use several measures of financial development and employ different econometric approaches have yielded mixed results. The first strand of literature provides evidence that financial development increases energy consumption. Sadorsky (2010) investigates the effect of financial development on energy consumption using a linear dynamic model and five indicators for financial development. He finds a significant positive relation when financial development is measured using stock market indicators.

Sadorsky (2011) also shows that a positive and significant relationship exists between financial development and energy consumption when financial development is measured using banking variables. Shahbaz and Lean (2012) use the autoregressive distributed lag bounds testing approach to cointegration and Granger causality tests to confirm the existence of a positive long-run relationship between energy consumption and financial development. Al-mulali and Lee (2013) investigate the impact of the financial development on energy consumption in the Gulf Cooperation Council (GCC) countries, they find a positive impact of the financial development on energy consumption both in the short and long run. Aslan et al. (2014) find that energy consumption Granger causes financial development. Islam et al. (2013) show that energy consumption is influenced by financial development.

The second strand of literature reveals mixed results on the impact of financial development on energy consumption. Dan and Lijun (2009) find that financial development is not the Granger reason of the energy consumption. Jalil and Feridun (2011) find that financial development has led to a decrease in environmental pollution and, as a result, decrease energy consumption. Coban and Topcu (2013) did not detect a significant relation between financial development and energy consumption in a panel of 27 EU countries. Ozturk and Acaravci (2013) find that financial development does not have an impact on energy consumption. Chang (2015) presents mixed results when assessing the impact of financial development on energy consumption. Topcu and Payne (2017) reveal the absence of a statistical relationship between the financial development index and energy consumption, however an increase in the value of the index slightly decreases energy consumption.

### 2.2. The ICT and Energy Consumption Nexus

Various studies examine the ICT-growth nexus, however few investigate the relation between ICT and energy consumption. The first line of research focuses on the different ways ICT could be used to decrease energy consumption. Toffel and Horvath (2004) argue that wireless technologies used when reading newspapers create lower environmental impacts and can realize energy savings. Barratt (2006) states that distance learning application is in direct relation with energy use.

The second line of researches analyses the direct and indirect effects of ICT on energy consumption. However, whether an ICT use increases energy efficiency or not remains a controversial question in the literature. Takase and Murota (2004) argue that an increase in the IT level could lead to an increase in energy consumption if the income effect caused by economic vitalization due to higher level of IT is stronger than the substitution effect caused by a change in the industrial structure, which is the case of the United States. If the opposite is true, then an increase in ICT investments will reduce energy consumption as in the case of Japan. Laitner (2002) speculated that the complexity and connectivity of the Internet generate uncertainty about the long-term impact on energy consumption. Cho et al. (2007) shows that ICT investment in some manufacturing sectors in South Korea will reduce electricity consumption, however investments in the service sector and most manufacturing sectors raise this consumption. Sadorsky (2012) examines the effect of ICT on electricity consumption in 19 emerging countries and finds that an increase in ICT leads to higher electricity consumption, hence the negative impact of ICT on energy consumption offsets the positive one. Ishida (2015) finds that ICT investments in Japan contribute to a moderate reduction in energy consumption in Japan. Afzal and Gow (2016) show that ICT variables positively affect electricity consumption in the Next eleven emerging economies. Saidi et al. (2017) investigate the impact of ICT on electricity consumption in a panel of 67 countries and show a positive and statistically positive relation between the two variables.

## 3. MODEL AND DATA

### 3.1. Empirical Model

This paper explores the impact of ICT and financial development on energy consumption in 11 MENA countries. Previous studies in the literature, Sadorsky (2010; 2011), Aslan et al. (2014), Chang (2015) and Topcu and Payne (2017), among others, modelled energy consumption as a function of income, prices and financial development. In addition, Sadorsky (2012), Afzal and Gow (2016) and Saidi et al. (2017), among others, considered electricity consumption as a function of income, prices and a measure of ICT. Our approach consists of estimating a dynamic panel data model. In this context, we follow previous studies in the literature and we develop an empirical model that assesses the impact of ICT, financial development, income and prices on energy consumption. Therefore, the dynamic empirical panel data model of energy consumption is specified as follows:

$$EC=f(ICT, FD, GDPC, P) \tag{1}$$

Where, *EC, ICT, FD, GDPC, P* represent energy consumption, *ICT* index, financial development, gross domestic product per capita (*GDPC*) and energy prices.

To obtain a tractable empirical model, the logarithmic transformation of Equation (1) is given by the following:

$$LEC_{it}=\beta_0+\beta_1 LEC_{i,t-1}+\beta_2 LICT_{it}+\beta_3 LFD_{it}+\beta_4 LGDPC_{it}+\beta_5 LP_{it}+v_{it}+\epsilon_{it} \tag{2}$$

Where, $L$ refers to the natural logarithm; $i=1,\ldots, N$ shows the subscript for each country in the panel, and $t=1,\ldots, T$ indicates the time period, $v_i$ represents the country specific effect and $\epsilon_{it}$ denotes the random error term. The parameters $\beta_2$, $\beta_3$, $\beta_4$ and $\beta_5$ represent the long-run elasticities of energy consumption relative to ICT, financial development, *GDPC* and energy prices respectively.

$LEC_{it}$ the dependent variable, denotes the energy consumption logarithm for the country i in year $t$. It is measured by energy use in KG of oil equivalent per capita. $LEC_{i,t-1}$ is the lagged dependent variable which indicates that energy consumption is expected to depend on its own lag, with $0 < \beta_1 < 1$. We incorporate the lagged dependent variable to account for the persistence in energy consumption as an impact of the underlying consumption habits. In addition, according to Sadorsky (2010), the lagged dependent variable is included to remove any possible autocorrelation. $LICT_{it}$ denotes the logarithm of the ICT index for the country i in year $t$ calculated as described in section 4.1. *ICT* index is constructed using three indicators as proxies for ICT namely Internet users (per 100 people) denoted by *INT*, mobile cellular subscriptions (per 100 people) denoted by *MCS*, and fixed telephone subscriptions (per 100 people) denoted by *FTS*. $LFD_{it}$ refers to the level of financial development for the country i in year $t$. Following Saidi et al. (2017), we use the domestic credit to private sector as a percentage of GDP as a proxy for the financial development. $LGDPC_{it}$ is the logarithmic *GDPC* for the country $i$ in year $t$. Income is represented by *GDPC* (constant 2010 US dollars). $LP_{it}$ denotes the logarithm of energy prices. Chang (2015) argues that since energy prices are not readily available for all countries, he can use consumer price index (CPI) as a proxy for energy prices. Moreover, Sadorsky (2012) suggested using CPI as a proxy for electricity prices. In fact, the CPI measures the fluctuations in the price of a typical basket of consumer goods and services. Fluctuations in consumer prices tend to follow the business cycle movements. In this context, the CPI reflects global movements in a basket of consumer goods and services hence it may or not serve as a proxy for energy prices. If energy prices follow the same trend as the CPI, then the CPI is considered as a good proxy. In this paper, and because long series for energy prices for the 11 MENA countries included in this study are not readily available, we will follow Chang (2015) and use the CPI (price, 2010 = 100) as a proxy for energy prices.

### 3.2. Data Source

This study uses a dynamic panel dataset for 11 MENA countries for the period 1995–2014. The specific countries included in this study and the time frame were dictated by data availability and the need for at least a minimum of T = 20 observations per country so that we can use the CCEMG estimator technique. Due to the lack of long data series for the remaining MENA countries, our dataset consists of 11 countries namely Bahrain, Egypt, Iran, Jordan, Kuwait, Lebanon, Morocco, Qatar, Saudi-Arabia, Tunisia and Turkey. It is a balanced panel analysis for the period between 1995 and 2014. Annual data for energy consumption (energy use in KG of oil equivalent per capita), *GDPC* (constant 2010 US dollars), CPI (price, 2010 = 100), Internet users (per 100 people), mobile cellular subscriptions (per 100 people) and fixed telephone subscriptions (per 100 people) were downloaded from the World Bank's World Development Indicators. The data for the domestic credit to private sector as a percentage of GDP was obtained from the Global Financial Development Database.

## 4. METHODOLOGY AND RESULTS

### 4.1. Principal Component Analysis

In an attempt to understand the dynamics of ICT and its impact on energy consumption, this study uses an index for ICT which incorporates data on three variables that serve as proxies for the level of ICT in a specific country. Particularly, we use the logarithm of Internet users (per 100 people) denoted by LINT, the logarithm of mobile cellular subscriptions (per 100 people) denoted by LMCS, and the logarithm of fixed telephone subscriptions (per 100 people) denoted by LFTS. In order to depict the presence of a multicollinearity problem, we investigate the correlation coefficients among the three ICT variables mentioned above. Results are presented in Table 1.

Table 1 shows the correlation matrix for the three ICT indicators. We can see that Internet users is highly correlated with mobile cellular subscriptions, with a correlation coefficient of 0.95 which is close to 1. Moreover, fixed telephone subscriptions is positively correlated with both Internet users and mobile cellular subscriptions with correlation coefficients of 0.36 and 0.39 respectively.

It is well established in the literature that assessing the impact of several variables that represent the components of the same structure within the same equation might generate a multicollinearity problem, particularly if those variables are highly correlated. Hence, we construct an ICT index using principal component analysis. The main advantage of using an index is that it allows us to combine different indicators of ICT into one single index that represents most of the characteristics from the original dataset. To the best of our knowledge, this is the first paper that studies the impact of ICT on energy consumption and uses an index as a measure for ICT. Previous studies in the literature use one or more indicators to proxy ICT but none constructed an index for ICT level. Among others, we cite Sadorsky (2012) in his paper ICT is measured using Internet connections, mobile phones or the number of PCs, Afzal and Gow (2016) use Internet users per 100 people, mobile cellular subscriptions per 100 people and ICT imports as a percentage of total exports as proxies for the level of ICT and Saidi et al. (2017) use the logarithmic of the Internet connections, and the logarithmic of mobile phones to measure ICT.

The index of ICT constructed using the principal component analysis will explain the variance-covariance structure of the given set of the three ICT variable through a linear combination of the variables of interest. The principal component analysis is based on the eigenvalue decomposition of the data covariance matrix, which indicates to which degree the standardized variance is explained by each component. Results are presented in Tables 2 and 3.

The eigenvalues in Table 2 reveal that the first principal component explains about 73% of the standardized variance, the second component explains 25%, while the third component only explains 1.9%. Hence, in this study we only extract the first principal component considering the eigenvalues. The contribution of each ICT variable is standardized by the variance of the first principal component. Therefore, the standard variances of Component 1 are used as the weights to construct the ICT index.

### 4.2. Cross-sectional Dependence and Unit Root Tests

The presented study focuses on the impact of ICT and financial development on energy consumption in a group of 11 MENA countries. Two major concerns arise in panel data studies.

First, in a dynamic panel data model, the country specific effects might be correlated with the lagged dependent variable which gives rise to endogeneity problem. In addition, when endogeneity of explanatory variables is suspected, ordinary least squares as well as fixed effect estimators generate inconsistent estimates (Caselli et al., 1996). To deal with the endogeneity problem, a dynamic GMM technique was developed by Arellano and Bover (1995) and Blundell and Bond (1998). However, one drawback of the GMM estimator is that it assumes an identical energy consumption level for each country, ignoring any parameter heterogeneity of cross-country panel data analysis. If the parameter heterogeneity across the countries is ignored, the regression estimates will be inconsistent and inferences based on these estimates will be misleading (Pesaran et al., 1999; Eberhardt and Teal, 2008; 2011).

The second major concern in panel data analysis is that individual units might be interdependent. In fact, MENA countries are trading

**Table 1: Correlation matrix of ICT variables**

| Variable | LINT | LMCS | LFTS |
|---|---|---|---|
| LINT | 1.0000 | | |
| LMCS | 0.9408 | 1.0000 | |
| LFTS | 0.3690 | 0.3988 | 1.0000 |

**Table 2: Principal components/correlation**

| Component | Eigenvalue | Difference | Proportion | Cumulative |
|---|---|---|---|---|
| Comp1 | 2.18878 | 1.4362 | 0.7296 | 0.7296 |
| Comp2 | 0.752578 | 0.693938 | 0.2509 | 0.9805 |
| Comp3 | 0.05864 | | 0.0195 | 1.0000 |

**Table 3: Principal components eigenvectors**

| Variable | Comp1 | Comp2 | Comp3 | Unexplained |
|---|---|---|---|---|
| LINT | 0.6403 | −0.3133 | 0.7014 | 0 |
| LMCS | 0.6461 | −0.2742 | −0.7123 | 0 |
| LFTS | 0.4155 | 0.9092 | 0.0269 | 0 |

partners, they share geographic proximity and are highly likely to be affected by common economic, financial or energy shocks that will spread out across MENA countries which leads to cross-section dependence in errors. As a result, when the panel data units are cross-sectionally dependent, the traditional estimates are inefficient and the corresponding standard errors are biased (Moscone and Tosetti, 2009).

Moreover, Kapetanios et al. (2011) point out that when errors are cross-sectionally dependent, conventional estimation techniques yield inconsistent estimates. Finally, Baltagi (2008) argues that cross-sectional dependence is considered a problem when dealing with macro panel data with time series ranging between 20–30 years, which is the case for this study as we have T = 20 years for each country. This study uses recent developments in panel data econometrics to test for the presence of cross-sectional dependence across the units of a panel. We use the Pesaran (2004) cross-sectional dependence test. This test performs well in relatively small samples and it is robust to non-stationarity as well as single or multiple structural breaks (Pesaran, 2004). Table 4 reports the results of the cross-sectional dependence test. The average correlation (corr) and absolute correlations (abs corr) of the residuals are also reported.

The cross-sectional dependence test rejects the null hypothesis of cross-sectional independence at 1% significance level for all the tested variables. Therefore, in light of the above results, and to avoid inconsistent estimation techniques, the presence of cross-sectional dependence will be taken into account in further steps of this study. Hence, since cross-sectional dependence correlation in panels is depicted, commonly used first generation unit root tests cannot be used. This paper will use second generation Pesaran (2007) CIPS test, which employs a common factor structure to account for cross-sectional dependence. Results of CIPS test reported in Table 5 shows that with the exception of the ICT index, each variable contains a unit root. All variables in the first difference are stationary over time.

### 4.3. Estimation Technique and Results

To address parameter heterogeneity and cross-section dependence issues, this study follows Pesaran (2006) in the use of the common CCEMG. This estimator accounts for cross-sectional dependence and allows the slope coefficients to be heterogeneous across panel countries. Several studies conducted by Pesaran (2006), Kapetanios et al. (2011) among others, indicate that CCE estimators produce consistent estimates and inferences even if we have a small cross-sectional dimension or if the variables are non-stationary and whether they are cointegrated or not. CCE estimates are also robust even if the data contains structural breaks. Equation (3) augments Equation (2) in consideration of the CCEMG technique:

$$\begin{aligned} LEC_{it} &= \beta_0 + \beta_1 LEC_{i,t-1} + \beta_2 LICT_{it} + \beta_3 LFD_{it} + \beta_4 LGDPC_{it} \\ &+ \beta_5 LP_{it} + \delta_1 LE\bar{C}_{i,t} + \delta_2 LI\bar{C}T_{it} + \delta_3 L\bar{F}D_{it} \\ &+ \delta_4 LG\bar{D}PC_{it} + \delta_4 L\bar{P}_{it} + v_{it} + \dot{o}_{it} \end{aligned} \tag{3}$$

Where, $LE\bar{C}_{i,t-1}$, $LI\bar{C}T_{it}$, $L\bar{F}D_{it}$, $LG\bar{D}PC_{it}$, $L\bar{P}_{it}$, represent the common factors to address the cross-sectional dependence issue. Table 6 presents the results.

The estimated coefficient of GDPC is positive and statistically significant at the 1% significant level.

As for ICT, we find a positive and statistically significant relation between ICT and energy consumption. As ICT increases by 1% energy consumption increases by 5.6%. This result is in line with previous results in the literature that depicted that ICT use can increase energy consumption (Sadorsky, 2012; Pesaran, 2006; Afzal and Gow, 2016; Saidi et al., 2017). Moreover, it advocates the theory that dictates that ICT use will increase energy consumption through the increased use of electricity.

Results in Table 6 also reveal that financial development, measured by domestic credit to private sector as a percentage of GDP, does not have a statistical significant impact on energy consumption. This result is consistent with Dan and Lijun (2009), Coban and Topcu (2013) and Ozturk and Acaravci (2013) who find that financial development does not have an impact on energy consumption. The price coefficient is in the correct sign but not statistically significant.

With respect to model robustness check, results of the cross-sectional dependence test show the absence of cross-sectional dependence. Moreover, the CIPS unit root test applied to the residuals strongly rejects the null of the presence of unit root in the residuals.

## 5. CONCLUDING REMARKS AND POLICY IMPLICATIONS

This paper examines how ICT and financial development affect the energy consumption in 11 MENA countries. Towards this

**Table 4: Cross sectional dependence test**

| Variable | CD test | P value | Corr. | Abs (corr.) |
|---|---|---|---|---|
| LEC | 4.91*** | 0.000 | 0.152 | 0.603 |
| LICT | 31.00*** | 0.000 | 0.959 | 0.959 |
| LGDPC | 14.58*** | 0.000 | 0.451 | 0.689 |
| LP | 30.03*** | 0.000 | 0.929 | 0.929 |
| LFD | 10.84*** | 0.000 | 0.335 | 0.561 |

Under the null hypothesis of cross-section independence CD~N (0,1). ***Denotes statistical significance at the 1% significance level.

**Table 5: Unit root test**

| Variable | Zt-bar | P value | First difference | Zt-bar | P value |
|---|---|---|---|---|---|
| LEC | −0.938 | 0.174 | dLEC | −7.742 *** | 0.000 |
| LICT | −2.108** | 0.018 | dLICT | −5.374*** | 0.000 |
| LGDPC | 1.670 | 0.953 | dLGDPC | −3.314 *** | 0.000 |
| LCPI | −0.743 | 0.229 | dLCPI | −1.888 ** | 0.030 |
| LFD | 0.596 | 0.724 | dLDP | −3.588 *** | 0.000 |

Null for CIPS tests: series is I (1). The CIPS statistics include an intercept and a trend. **,***Denote that we reject the null of unit root at the 5% and 1% significance level respectively

**Table 6: CCEMG estimation results**

| Variable | Coef. | Std. Err. | First difference | Zt-bar |
|---|---|---|---|---|
| LEC(−1) | −0.242322** | 0.116295 | −2.08 | 0.037 |
| LICT | 0.056129** | 0.024159 | 2.32 | 0.020 |
| LGDPC | 0.726894*** | 0.273354 | 2.66 | 0.008 |
| LP | −0.483021 | 0.421272 | −1.15 | 0.252 |
| LFD | −0.029867 | 0.062659 | −0.48 | 0.634 |
| Cons | −1.54332 | 1.97607 | −0.78 | 0.435 |
| Cross-sectional dependence test | −1.91 | | | 0.057 |
| CIPS test | −4.397*** | | | 0.0000 |

**.*** indicate that the coefficient is statistically significant at the 5% and 1% significance levels respectively. LEC(−1) denotes the lag of LEC. *CCEMG: Correlated* effect mean group estimator

end, a dynamic heterogeneous panel technique that accounts for cross-sectional dependence among the panel units has been adopted. Moreover, an index for ICT using principal component analysis is constructed using three variables for ICT, Internet users (per 100 people), mobile cellular subscriptions (per 100 people) and fixed telephone subscriptions (per 100 people). To the best of the author's knowledge, this is the first paper that addresses the homogeneity and cross-sectional issues and uses the CCEMG estimator to analyze the relationship between ICT as an index, financial development and energy consumption in the MENA region.

Using a panel of 11 MENA countries, results indicate that an increase in the ICT use, measured by the index of ICT, will increase the demand for energy. The coefficient for ICT is positive and statistically significant which confirms results in the previous literature that ICT might increase energy consumption through the increase in electricity use (Pesaran, 2006; Sadorsky, 2012; Afzal and Gow, 2016; Saidi et al., 2017). Moreover, results show that financial development did not have a statistical significant impact on energy consumption. This finding parallels the result of many previous studies in the literature (Dan and Lijun, 2009; Coban and Topcu, 2013; Ozturk and Acaravci, 2013).

Regarding the policy implications, and since ICT use is empirically found to increase energy consumption in 11 MENA countries, policies designed to increase the use and adoption of ICT should be implemented, taking into consideration the negative impact on the environment due to an increase in energy consumption. An increase in the use of ICT should be accompanied by policies to reduce energy consumption and increase energy savings potentials in all aspects. One possibility could be using energy saving techniques or more efficient devices in term of electricity consumption. As for financial development and energy consumption, results reveal that a more developed financial system will not increase energy consumption in the 11 MENA countries considered in this study. Hence, policies to promote financial markets development can be executed without concerns about probable adverse effects on energy consumption.

Finally, one has to note that this study might suffer from some limitations regarding the sample size. Due to data availability, only 11 countries of the MENA region were included in the sample. However, even though the research might suffer from some limitations, results regarding the impact of ICT and financial development on energy consumption remain adequate and highlight the importance of the adoption of energy savings policies along with the use of more ICT in the MENA region. One possible extension of the work would be to include more countries and longer time series as data become gradually available. Another possible future work would be to realize a similar study in the context of GCC countries or to conduct a research on the Arab countries, differentiating between oil importer and oil exporter countries.

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