The Role of Information Communication Technology and Economic Growth in Recent Electricity Demand: Fresh Evidence from Combine Cointegration Approach in UAE

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Abstract: This paper investigates relationship between information communication technology (ICT), economic growth and electricity consumption using data of UAE over the period of 1975-2011.We have tested the unit properties of variables and the Bayer and Hanck combined cointegration approach for long run relationship. The innovative accounting approach is applied to test the robustness of the VECM Granger causality findings. Our empirical results confirm the existence of cointegration between the series. We find that ICT adds in electricity demand but electricity prices lower it. Income growth increases electricity consumption. The non-linear relationship between ICT and electricity consumption is an Inverted U-shaped. The causality results reveal that ICT and electricity prices Granger cause electricity demand. The feedback effect exists between economic growth and electricity consumption.
Keywords: ICT, Growth, Electricity, UAE

Introduction

In existing energy literature, the relationship between information and communication technologies (ICT), energy usage and economic growth is a topic which has gain momentum recently. The theoretical literature on the relationship between ICT and energy usageis dated back to 1950's. The literature was, however, stagnant until late 1980's[1] and early 1990's[2]. The effect of extensive utilization of IT on electricity was repeatedly ignored or believed to be of less importance because many of articles on the relationship between IT usage and energy consumptions were written before the pervasive adoption of mobile phones and the internet (Sadorsky, 2012). In a broad sense, technological developments have formed many revolutions in the world. Resultantly, energy markets have observed many transformations. Such technological developments are largely driven by trade openness, liberalization and subsequent emergence of new technologies. With the advent of technological revolutions, ICT emerged as a useful source to drive economic growth with less energy consumption. Concurrently, the role of ICT in forming energy needs and consumer attitude towards energy saving have increased enormously. ICT is considered an enabler to advance energy efficiency across the economy. One of the most striking features of ICT is the momentum of adoption and innovation. On other hand, however, ICT is also considered as a source of energy consumption. Walker (1985) for instance, pointed out that as economies moves toward greater use of Information Technology (IT), overall energy demand would tend to decrease, extensive usage of IT will however, add to electricity's importance in an economy. In addition, the relationship between environment and ICT is multifaceted and complex, since ICT accounts both positive and negative roles. On positive note, ICT Impacts transport and travel substitution dematerialization and online delivery, greater

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[1] Walker, (1985, 1986) highlighted the significant role of information Technology within the energy sector and it associated costs and benefits.

[2] Chen, (1994) underscores the conceptual background, realities and limits of substitution of information for energy.

energy efficiency in production and use, product stewardship and recycling and, a host of monitoring and management applications. On negative side, ICT does affect energy consumption used directly and for cooling, short product life cycles and e-waste, energy consumption and the materials used in the production and distribution of ICT equipment, and exploitative applications such as remote sensing for unsustainable over-fishing (Daly, 2003).

The ICT industry has developed very swiftly over the past two decades with the pervasive adoption of the internet, cell phones and digital computers. With the emergence of new technologies in ICT, old technologies (e.g. Smart phones and personal computers) are being replaced, which let users watch streaming videos and surf internet. These kinds of technologies propel positive network effect on users and allow users to share pictures, data and video, such activities, however increase the demand for electricity. To manage smooth operations ICT industries depend heavily on gigantic data centers, electricity-consumingnetwork ofsemiconductors and communication towers (Sadorsky, 2012). According to an estimate, energy consumption from data centers doubles over the period of 2000-2005 and total electricity usage roseto an average annual rate of 16.7% per year (Koomey, 2008). Kanter, (2008) noted ICT is responsible for global carbon emissions by approximately 2%.

According to a report of the Smart 2020[3], on aggregate, ICTs could bring approximately 7.8 $GtCO_2$ of emissions savings by 2020. This characterizes a considerable quantity of the reductions below 1990 levels that scientists and economists suggested by 2020 to circumvent a hazardous climate change. In economic terms, ICT-enabled energy efficiency transforms into approximately $946.5 billion of cost savings and suggested that it is a potential prospect,

[3] SMART 2020- Enabling the low carbon economy in the information age

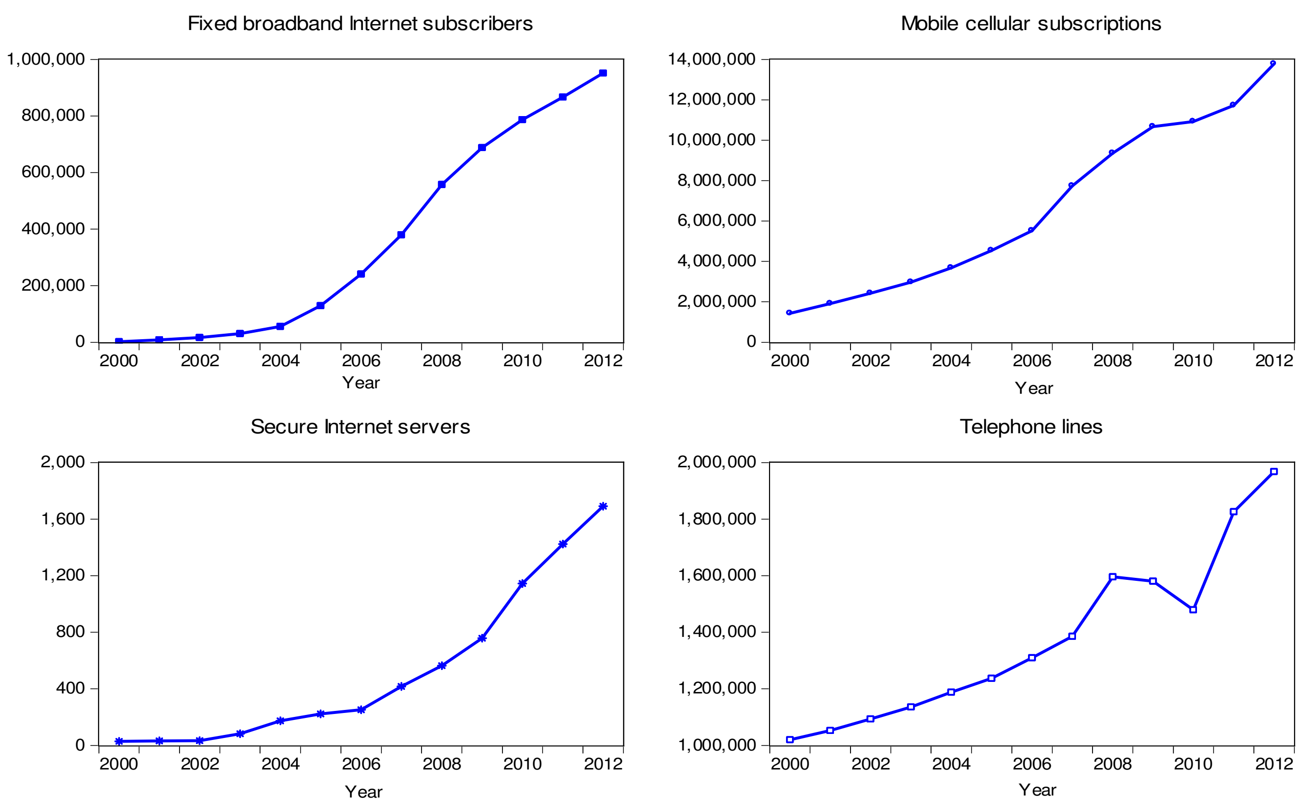
whichcannot be disregarded. According to 2013 press release[4] of International Telecommunication Union (ITU), ICT data envisage that soon there will be as many mobile-cellular subscriptions as humans living on the planet with the statistics set to cross 7 billion in early 2014. The reported further reveals that on aggregate, more than half of mobile subscriptions are now in Asia, which continues to be a hub of market growth and overall global mobile penetration rate, will reach to 96% by the end of 2013. This growing trend of ICT implies that in coming years demand for energy will further grow for extensive utilization of ICT in economies which will have significant implications for economic progress. Since its utilization of ICT has been seen as a critical factor in economic development and it has been argued that ICT represents new ‘General Purpose Technology’, with the prospective of transforming economic developments into a “New Economy,” engendering a constant boost in economic growth through development of technologies and innovation (*Info*Dev, 2007).

Given that ICT is playing a larger role in energy usages across the economies and the surge in adoption of extensive ICT usages brings up a few interesting questions such as: 1) How does the increase in ICT usage affect energy consumptions and consequently economic growth? (Linear and nonlinear), 2) Is there any long-term relationship between these variables? 3) What are the short-run relationships between these variables? (4) What are the directions of the causality? (5) What will be the policy implications for ICT in general and electricity demand in particular if causality is found between these variables? Our study attempts to answer these questions in case of United Arab Emirates (UAE) with the second largest ICT infrastructure after Saudi Arabia in Middle East.

[4]http://www.itu.int/net/pressoffice/press_releases/2013/05

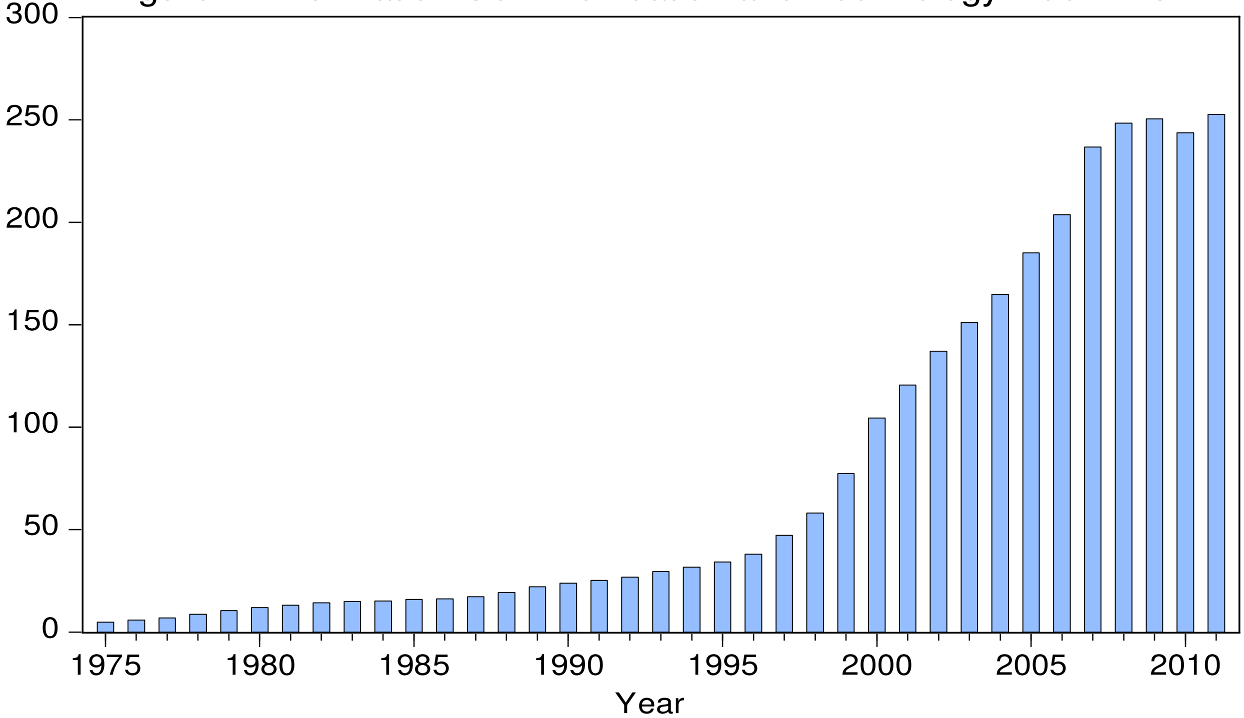
During the last two decades, ICT sector of UAE has shown afast track growth and placed 33rd in IDI 2012[5]. In term of revenue generation, the UAE telecommunication market has witnessed anannual growth of 20% from 2005 (USD 8.2 billion) to 2008 (13.6 billion).The findings reported in a household survey, recently conducted by country Telecommunication Regulatory Authority (TRA, 2012)[6] shows that approximately all residents use a mobile phones and 85% population regularly uses the internet. In the use sub-index which capture ICT intensity, UAE record significant progress. The penetration has reached to 51% in 2012 against the 22% of previous year.

Figure-1- General ICT trend in United Arab Emirates (UAE)



[5]http://gulfnews.com/business/technology/uae-makes-biggest-gain-in-ict-rankings-1.1259075
[6]http://www.tra.gov.ae/ict_in_uae.php

Figure-2: Information Communication and Technology Index in UAE



To answer the research question posed above, we applied energy demand model to explore the relationship between ICT and electricity consumption by incorporating electricity prices and economic growth using the data of UAE. The cointegration among the variables is investigated by applying Bayer and Hanck, (2013) combined cointegration approach. The VECM Granger casual approach is applied to detect the direction of causality among the series. Our results indicate that ICT adds in electricity consumption, electricity prices and income are inversely linked with electricity demand. The non-linear relationship between ICT and electricity consumption is an inverted U-shaped. We find that ICT Granger causes electricity consumption.

II. Literature Review

With rapid technological developments, the role of ICT in economic growth has attracted significant attention. Based on aggregate data, early evidences suggested that information technology; particularly computers have effect on growth or productivity (e.g. Gordon, 2000;

Jorgenson and Sitroh, 1999; Berndt and Morrison, 1995). Ketteni et al. (2012) noted that most of previous studies have used aggregate production function by assuming competitive market and constantreturns to scale. These limitations often make the relationship between growth and information technology spurious. Recently, research has shifted to use disaggregated data to enable one to use more adequate estimation techniques. Such estimation techniques suggest that firms that manufacture ICT products have engrossed significant resources and gained from odd technological advancement and this is accommodated in total factor productivity (TFP) growth in ICT (e.g. Oliner and Sichel, 2000; Hendel, 1999; Jorgenson, 2001, 2004; Jorgenson et al. 2002; Barua and Lee, 1997). Few studies suggest that there is significant positive relationship between ICT and economic growth (Hoon, 2003; Basu et al. 2003; Biscourp et al. 2002).

The relationship between ICT and energy consumption is timely and important subject that is infrequently examined and most of the previous work on this subject is carried out on developed economies data (Sadorsky, 2012). This section reviews some selected previous literature on ICT-energy consumption and ICT-economic growth nexus. Romm, (2002) examined the energy usage intensity of ICT sectors in United States by comparing the Pre-Internet period (1992-1995) and internet period (1996-2000) and noted that ICT sector are less energy demanding as compared to manufacturing sectors. Romm, (2002)exposed that United States energy consumption and GDP increased yearly at average rate of 1% and 4% respectively in the internet era as compared to 2.4% and 3.2% respectively in pre-internet era. Two different effects are reported behind this disjoint of energy and economic growth. First, ICT sector is less energy consuming than manufacturing sector. Second, internet emerges as a crucial factor for promoting efficiency in each sector of US economy. Romm, (2002) further noted that internet appears to be propelling efficiencies instead of increasing electricity demand. In case of Germany, Schaefe et al. (2003) examined the energy consumption of mobile phones (charging losses included). They calculated both mobile phone and network usages. Mobile phones energy usage is calculated using profile of different customers. Their results showedeven if low efficiencies of the charging processes are included in the calculation of energy consumption, still it is the operation of network equipments which causes energy demand for mobile phone services not by the handsets itself. Takase and Murota, (2004) examined the effect of information technology investment on energy consumption and CO_2 emissions in US and Japan. They noted that increase in information technology lowers energy intensity. They further documented that increase or decrease in energy usage is driven by strength of trend (i.e. economic stimulation from increases in IT usage causes income effect or changes in industrial structure causes substitution effect).

In case of French service sector, Collard et al. (2005) examined the relationship between ICT and energy consumption using factor demand model. After controlling for alternative determinants such as prices, heated areas, technical progress, their result suggests that impact of communication technology is greater than information technology on energy usages. Using logistic growth model, Cho et al. (2007) examined the effects of investment in ICT, electricity price and oil prices on electricity consumption in South Korea. Their findings reported that ICT investment in manufacturing industries that usually consume more amounts of energy increases input factor substitution to electricity intensive from labor intensive. Their results further suggest that ICT investment in few manufacturing sector and in services sector consume more electricity whereas, ICT investment in some specific manufacturing sector is helpful in decreasing electricity consumption. They noted that electricity prices significantly influence electricity consumption in industrial sector in half of South Korea. The European Commission e-Business Watch, (2008) comprehensively examined the effects of ICT on electricity consumption in selected countries[7]. Their findings indicated that, overall ICT might not essentially decrease energy consumption at absolute level. The diffusion of communication technologies, however have an impact on energy consumption reduction at sector level. They further noted that computer and software technologies diffusion likely to raise the electricity consumption. In case of Denmark, Røpke et al. (2010) carried out a case study in 2007-2008 to explore ICT related transformation of everyday practice of household electrification. They noted that 1950, 97% of Danish household's consumption of electricity was for lighting, while this percentage reduced in 2006 to 11% (household electricity consumption) and with 59% used for heating and cooking and 30% used for miscellaneous. They argued that integration of ICT in everyday practices cause increase in electricity consumption. Using GMM estimation, Sadorsky (2012) empirically investigates the impact of ICT on electricity consumption in emerging economies. Sadorsky, (2012) measured ICT using mobile phones, internet connection and numbers of personal computers (PCs). His finding exposed that there is positive relationship between electricity consumption and ICT.

II. Model Construction, Methodological Framework and Data Collection

We explore the relationship between ICT and electricity consumption by incorporating electricity prices and economic growth in electricity demand function using data of United Arab Emirates over the period of 1975QI-2011QIV. The general discussion in existing energy literature leads us to use a general electricity demand function as following:

[7] Denmark, Finland, France, Germany, Italy, Spain, and UK

$$EC_t = f(ICT_t, EP_t, Y_t) \quad (1)$$

We have transformed all the series into logarithm to make the model estimable. The estimable empirical equation is modeled as following:

$$\ln EC_t = \beta_1 + \beta_2 \ln ICT_t + \beta_3 \ln EP_t + \beta_4 \ln Y_t + \mu_t \quad (2)$$

where, $\ln$ is natural log-form, EC_t is electricity consumption, ICT_t is for information communication and technology (index), EP_t is electricity prices, Y_t is for economic growth proxies by real GDP per capita. μ_t is error term assumed to have normal distribution with zero mean and constant variances. We combed world development indicators (CD-ROM, 2012) to collect data on real GDP, electricity consumption (kWh), electricity prices and, information communication and technology (ICT) proxies by (mobile phones, internet connection and numbers of personal computers)[8]. The population series is also used to convert series into per capita except electricity prices and information communication and technology. The study covers the period of 1975-2011 using quarter frequency data[9].

In the time series analysis, series are apparently integrated if two or more series are individually integrated. To address the cointegration phenomenon, several techniques have been developedin

[8]We have generated an index of ICT using Principle Component Analysis. The data is available from authors upon request.

[9] We have converted all the annual series into quarterly data to avoid the problem of degree of freedom and efficient empirical results. We used quadratic match sum method to transform all the variables into quarter frequency following Romero, (2005) and, McDermott and McMenamin, (2008).

time series literature. These techniques include Engle and Granger, (1987) cointegration approach, Johansen (1991) Johansen maximum Eigen value test, Phillips and Ouliaris (1990) Phillips–Ouliaris cointegration test and Error Correction Model (ECM) based F-test of Peter Boswijk (1994), and the ECM based t-test of Banerjee et al. (1998). These tests however, require some prerequisites to be considered robust and thus having exclusive attributes. The Engle and Granger, (1987) cointegration approach, for instance requires stationarity among non-stationary variables and useful for limited data set length. Similarly, Johansen (1991) maximum Eigen value test allow more than one co integrating vector and consider more flexible and generally applicable than Engle and Granger, (1987) test. Different test, however yield different conclusion. To enhance the power of cointegration test, with the unique aspect of generating a joint test-statistic for the null of no-cointegration based on Engle and Granger, Johansen, Peter Boswijk, and Banerjee tests, the so-called B*ayer-Hanck* test is newly proposed by Bayer and Hanck (2013). Since this new approach allows us to combine various individual cointegration test results to provide a more conclusive finding, following Bayer and Hank (2013), the combination of the computed significance level (*p*-value) of individual cointegration test is carried out through Fisher's formulas as follows:

$$EG-JOH=-2\left[\ln(p_{EG})+(p_{JOH})\right] \tag{3}$$

$$EG-JOH-BO-BDM=-2\left[\ln(p_{EG})+(p_{JOH})+(p_{BO})+(p_{BDM})\right] \tag{4}$$

Where p_{EG}, p_{JOH}, p_{BO} and p_{BDM} are the *p*-values of individual cointegration tests respectively. The conclusion of having information on cointegration is based on the estimated Fisher statistics.

If critical values provided by the Bayer and Hank (2013) are less than the estimatedFisher, the null hypothesis of no cointegration is rejected.

After having information on cointegration relationship between the variables, we used the Granger causality approach to examine the causality between the variables. We used vector error correction method (VECM), following existence of cointegration between the variables by the following matrix formulation.

$$\begin{bmatrix} \Delta \ln EC_t \\ \Delta \ln ICT_t \\ \Delta \ln EP_t \\ \Delta \ln Y_t \end{bmatrix} = \begin{bmatrix} b_1 \\ b_2 \\ b_3 \\ b_4 \end{bmatrix} + \begin{bmatrix} B_{11,1} & B_{12,1} & B_{13,1} & B_{14,1} \\ B_{21,1} & B_{22,1} & B_{23,1} & B_{24,1} \\ B_{31,1} & B_{32,1} & B_{33,1} & B_{34,1} \\ B_{41,1} & B_{42,1} & B_{43,1} & B_{44,1} \end{bmatrix} \times \begin{bmatrix} \Delta \ln EC_{t-1} \\ \Delta \ln ICT_{t-1} \\ \Delta \ln EP_{t-1} \\ \Delta \ln Y_{t-1} \end{bmatrix} + \ldots + \begin{bmatrix} B_{11,m} & B_{12,m} & B_{13,m} & B_{14,m} \\ B_{21,m} & B_{22,m} & B_{23,m} & B_{24,m} \\ B_{31,m} & B_{32,m} & B_{33,m} & B_{34,m} \\ B_{41,m} & B_{42,m} & B_{43,m} & B_{44,m} \end{bmatrix}$$

$$\times \begin{bmatrix} \Delta \ln EC_{t-1} \\ \Delta \ln ICT_{t-1} \\ \Delta \ln EP_{t-1} \\ \Delta \ln Y_{t-1} \end{bmatrix} + \begin{bmatrix} \zeta_1 \\ \zeta_3 \\ \zeta_3 \\ \zeta_4 \end{bmatrix} \times (ECM_{t-1}) + \begin{bmatrix} \mu_{1t} \\ \mu_{2t} \\ \mu_{3t} \\ \mu_{4t} \end{bmatrix} \tag{5}$$

Where difference operator is $(1-L)$ and ECM_{t-1} is the lagged error correction term, generated from the long run association. The long run causality is found by significance of coefficient of lagged error correction term using t-test statistic. The existence of a significant relationship in first differences of the variables provides evidence on the direction of short run causality. The joint χ^2 statistic for the first differenced lagged independent variables is used to test the direction of short-run causality between the variables. For example, $B_{12,i} \neq 0 \forall_i$ shows that ICT Granger causes electricity consumption and ICT is Granger of cause of electricity consumption if $B_{11,i} \neq 0 \forall_i$.

III. Results and their Discussions

Primarily we have applied the Ng-Perron unit root test to avoid the problem of spuriousness. Standard cointegration approaches require information about the unit root properties of the variables.Traditional unit root test such as ADF, DF-GLS and PP provide ambiguous results once data span is small. Ng-Peroon unit root test provides consistent and efficient results and suitable for small data set. The results of Ng-Peroon unit root test are reported in Table-1. We find that all the variables are found to be non-stationary at level (intercept and trend). After difference, electricity consumption (EC_t), information communication and technology (ICT_t), electricity prices (EP_t) and economic growth (Y_t) are stationary. This implies that all the variables are found to be integrated at I(1).

Table-1: Ng-Perron Unit Root Test Analysis

Variables	MZa	MZt	MSB	MPT
$\ln EC_t$	-1.56671	-0.62342	0.39792	36.1139
$\ln ICT_t$	-10.5671	-2.26182	0.21404	8.80689
$\ln EP_t$	-0.80259	-0.34304	0.42741	43.4726
$\ln Y_t$	-4.19427	-1.15239	0.27475	19.0400
$\Delta \ln EC_t$	-30.0868*	-3.87767	0.12888	3.03411
$\Delta \ln ICT_t$	-23.6907**	-3.44092	0.14524	3.85128
$\Delta \ln EP_t$	-85.7574*	-6.51194	0.07593	1.20984
$\Delta \ln Y_t$	-28.6523*	-3.68945	0.12877	3.73971

The unique order of integration of the variables suggests to apply the Bayer and Hanck combined cointegration tests such as EG-JOH, and EG-JOH-BO-BDM tests. It is necessary to select the appropriate lag length of the variables to compute Fisher-statistic to examine whether cointegration exists among the series. The Fisher-statistic is sensitive with lag length selection. We choose lag order 6 following the minimum value of Akaike information criterion due to its superior properties. The results are reported in Table-2.

Table-2: Lag Order Selection

VAR Lag Order Selection Criteria						
Lag	LogL	LR	FPE	AIC	SC	HQ
1	2257.431	2826.385	1.54e-19	-31.9633	-31.5430	-31.7925
2	2423.330	310.4678	1.82e-20	-34.1047	-33.3482*	-33.7973*
3	2429.194	10.6389	2.10e-20	-33.9599	-32.8673	-33.5159
4	2432.678	6.1228	2.52e-20	-33.7811	-32.3523	-33.2005
5	2485.364	89.5658	1.50e-20	-34.3052	-32.5402	-33.5879
6	2514.888	48.5039*	1.24e-20*	-34.4984*	-32.3972	-33.6445
7	2516.796	3.0245	1.53e-20	-34.2970	-31.8597	-33.3066
8	2522.133	8.1582	1.81e-20	-34.1447	-31.3712	-33.0176

* indicates lag order selected by the criterion

LR: sequential modified LR test statistic (each test at 5% level)

FPE: Final prediction error

AIC: Akaike information criterion

SC: Schwarz information criterion HQ: Hannan-Quinn information criterion

As the unit root test shows that all variables follow the $I(1)$, the combined cointegration tests are proceeded. Table-3 illustrates the combined cointegration tests including the EG-JOH, and EG-JOH-BO-BDM tests. The result reveals that Fisher-statistics for EG-JOH and EG-JOH-BO-BDM tests, in case of $\ln EC_t$ and $\ln Y_t$ are greater than 5% critical values indicating that both EG-JOH and EG-JOH-BO-BDM tests statistically reject the null hypothesis of no cointegration between variables. However, the result of combined cointegration tests for the case of $\ln ICT_t$ and $\ln EP_t$ seem to support the null hypothesis of no cointegration. Our finding shows that there is a cointegration among the series. This shows that there is s long run relationship between ICT, electricity prices, economic growth and electricity consumption over the period of 1975QI-2011QIV in case of UAE.

Table-3: The Results of Bayer and Hanck Combine Cointegration Tests

Estimated Models	EG-JOH	EG-JOH-BO-BDM	Cointegration
$EC_t = f(ICT_t, EP_t, Y_t)$	25.707	125.222	Yes
$ICT_t = f(EC_t, EP_t, Y_t)$	7.412	10.586	No
$EP_t = f(EC_t, ICT_t, Y_t)$	6.704	9.368	No
$Y_t = f(EC_t, ICT_t, EP_t)$	55.227	57.692	Yes
Significance level	Critical Values	Critical Values	
1 per cent level	16.259	31.169	

5 per cent level	10.637	20.486	
10 per cent level	8.363	16.097	
Note: **represents significant at 5 per cent level.			

The marginal contribution of ICT, electricity prices and economic growth to electricity demand is reported in Table-4. We find that ICT facilitates electricity consumption at 1 percent significance level. Keeping other variables constant, a 1 percent increase in ICT will increase electricity consumption by 0.3796 percent. Electricity prices are negatively related with electricity consumption and it is significant at 1 per cent level. A 0.6945 per cent decline in electricity consumption is due to 1 per cent increase in electricity prices, all else is same.The economic growth is inversely linked with electricity consumptionsignificantly at 1 per cent. A 1 per cent increase in economic growth will decline electricity consumption by 0.0871 per cent by keeping other things constant.

Table-4: Long and Short Run Analysis

Dependent Variable = $\ln EC_t$				
Panel- A: Long Run Results				
Variables	Coefficient	Prob. Values	Coefficient	Prob. Values
Constant	2.8958*	0.0000	2.9361***	0.0924
$\ln ICT_t$	0.3796*	0.0000	1.5905*	0.0000
$\ln ICT_t^2$	….	….	-0.1679*	0.0000
$\ln EP_t$	-0.6945*	0.0000	0.0709	0.5153

$\ln Y_t$	-0.0871*	0.0045	-0.2039**	0.0565
R^2	0.9428		0.5991	
$Ajd - R^2$	0.9414		0.9536	
Panel-B: Short Run Results				
Constant	0.0011	0.1470		
$\Delta \ln ICT_t$	0.3211*	0.0002		
$\Delta \ln EP_t$	-0.1548**	0.0501		
$\Delta \ln Y_t$	0.1747*	0.0084		
ECM_{t-1}	-0.0291*	0.0035		
R^2	0.2550			
$Ajd - R^2$	0.2345			
D-W Test	2.5017			
F-statistic	12.1830*			
Diagnostic Test				
Test	F-statistic	Probability		
$\chi^2 SERIAL$	0.0714	0.9228		
$\chi^2 ARCH$	0.2222	0.6649		
$\chi^2 WHITE$	0.4054	0.8622		
$\chi^2 REMSAY$	0.2554	0.7459		
Note: *, ** and *** represent significance at 1%, 5% and 10%level respectively. $\chi^2 SERIAL$ is for serial correlation, $\chi^2 ARCH$ for autoregressive				

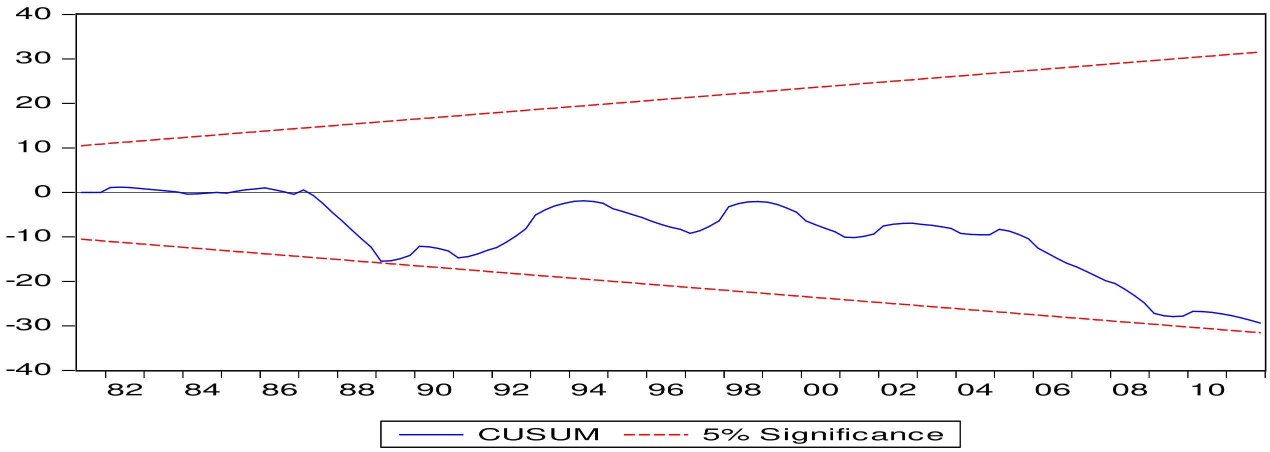
conditional heteroskedasticity, $\chi^2 WHITE$ for white heteroskedasticity and $\chi^2 RAMSEY$ for Ramsey Reset test.

We have also incorporated non-liner term of ICT ($\ln ICT_t^2$) to test whether relationship between ICT and electricity consumption is U-shaped or an inverted U-shaped. We find that non-linear relationship between ICT and electricity consumption is an inverted U-shaped. It is noted that 1 per cent increase in ICT increases electricity consumption by 1.5905 percent but negative sign of squared term ($\ln ICT_t^2$) corroborates the delinking of electricity consumption and ICT, at higher level of ICT economic development. This validates that ICT increases electricity consumption initially and electricity demand is declined after threshold level of ICT development.

In short run, ICT increases electricity consumption at 1 per cent level of significance. Electricity prices are inversely linked with electricity demand and it is statistically significant at 5 per cent level. The relationship between economic growth and electricity consumption is positive. It shows that economic growth adds in electricity demand. The significant and negative coefficient of lagged ECM_{t-1} (-0.0291) confirms the established long run relationship between the variables. The term is significant at the 1% level (lower segment of Table-4), which suggests that short run deviations in electricity consumption are corrected by 2.91 per cent every quarter towards long run equilibrium and may take 8 years and 6 months to reach stable long run equilibrium path. The lower segment of Table-7 deals with diagnostic tests. The results indicate that error term has normal distribution. There is no evidence of autoregressive conditional heteroskedasticity and same inference is drawn for white heteroskedasticity. The functional form of short run model is well constructed confirmed by Ramsey Reset test statistic. The results of stability tests such as

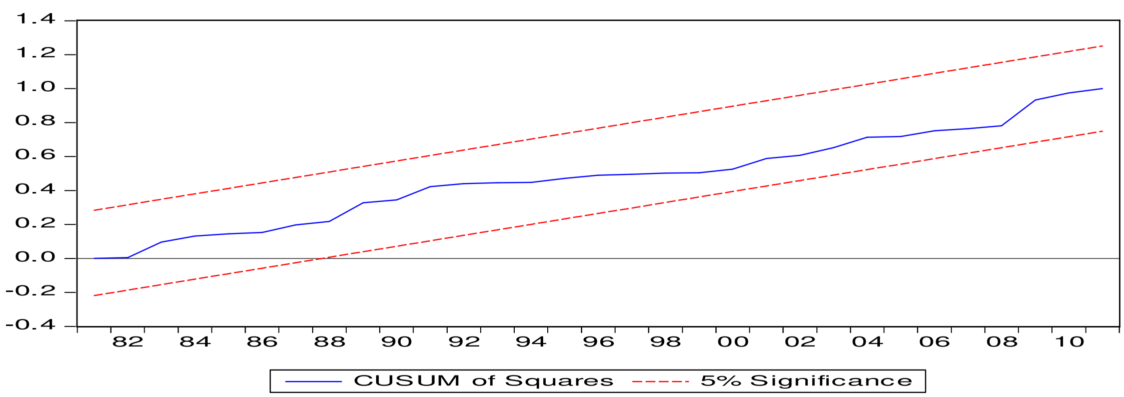
CUSUM and CUSUMsq are shown in Figure-3 and 4. The results of CUSUM and CUSUMsq tests indicate the stability of the ARDL parameters.

Figure-3: Plot of Cumulative Sum of Recursive Residuals



The straight lines represent critical bounds at 5% significance level

Figure-4: Plot of Cumulative Sum of Squares of Recursive Residuals



The straight lines represent critical bounds at 5% significance level

The VECM Granger Causality Analysis

There must be uni-or bidirectional causality between/ among the series if cointegration is confirmed. We examine this relation within the VECM framework. Such knowledge is helpful in designing appropriate energy and ICT policies for sustainable economic growth.The causality results are reported in Table-5. In long run, the unidirectional causality is found running from information communication and technology (ICT) to electricity consumption. Electricity consumption is also Granger cause of electricity prices. The feedback effect is found between electricity consumption and economic growth. The unidirectional causality is also found running from ICT and electricity prices to economic growth. The short run causality results note that ICT Granger causes electricity consumption and the bidirectional casual relationship is found between electricity prices and ICT. ICT and electricity prices Granger cause economic growth. The neutral effect exists between ICT and economic growth. The joint causality analysis also confirms our long-short runs casual results.

Table-5: The VECM Granger Causality Analysis

Dependent Variable	Direction of Causality								
	Short Run				Long Run	Joint Long-and-Short Run Causality			
	$\Delta\ln EC_{t-1}$	$\Delta\ln ICT_{t-1}$	$\Delta\ln EP_{t-1}$	$\Delta\ln Y_{t-1}$	ECT_{t-1}	$\Delta\ln EC_{t-1}, ECT_{t-1}$	$\Delta\ln ICT_{t-1}, ECT_{t-1}$	$\Delta\ln EP_{t-1}, ECT_{t-1}$	$\Delta\ln Y_{t-1}, ECT_{t-1}$
$\Delta\ln EC_t$	….	0.3616* [0.6972]	0.8438 [0.4323]	2.3093 [0.1032]	-0.0144** [-2.1479]	….	2.1943* [0.0052]	3.7000* [0.0098]	3.0230** [0.0102]
$\Delta\ln ICT_t$	2.1338 [0.1229]	….	0.8756* [0.4192]	0.1287 [0.8496]	….	….	….	….	….
$\Delta\ln EP_t$	1.5978 [0.2080]	0.8203* [0.4424]	….	8.4782* [0.0003]	….	….	….	….	….
$\Delta\ln Y_t$	1.2820 [0.2808]	3.0257** [0.0518]	5.1941* [0.0067]	….	-0.0185** [-2.0698]	….	3.1160** [0.0433]	3.5625** [0.0160]	5.2378* [0.0019]

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

The direction of causality between electricity consumption, information communication technology (ICT), electricity prices and economic growth by applying innovative accounting approach (IAA) rather than the VECM Granger causality method. The VECM Granger causality is suitable to detect a causal relationship between the variables within the sampled period. To determine causality ahead the sample period, the innovative accounting approach is much better. The innovative accounting approach is the combination of variance decomposition and the impulse response function. The variance decomposition approach indicates the magnitude of predicted error variance for a series accounted for by innovations from each of the independent variable over different time-horizons beyond the selected time period. It is pointed by Pesaran and Shin, (1999) that generalized forecast error variance decomposition method shows the proportional contribution in one variable due to innovative shocks stemming in other variables. The main advantage of this approach is that like orthogonalized forecast error variance decomposition approach; it is insensitive with ordering of the variables because ordering of the variables is uniquely determined by VAR system. Further, the generalized forecast error variance decomposition approach estimates the simultaneous shock effects. Engle and Granger, (1987) and Ibrahim, (2005) argued that with VAR framework, variance decomposition approach produces better results as compared to other traditional approaches. The results of variance decomposition approach are described in Table-8. The empirical evidence indicates that a 42.36 percent portion of electricity consumption is contributed by its own innovative shocks and one standard deviation shock in ICT, economic growth explain energy demand by 10.49 and 42.42percent respectively. The contribution of electricity prices to electricity consumption is 46.11 percent.

Table-8: Variance Decomposition Approach

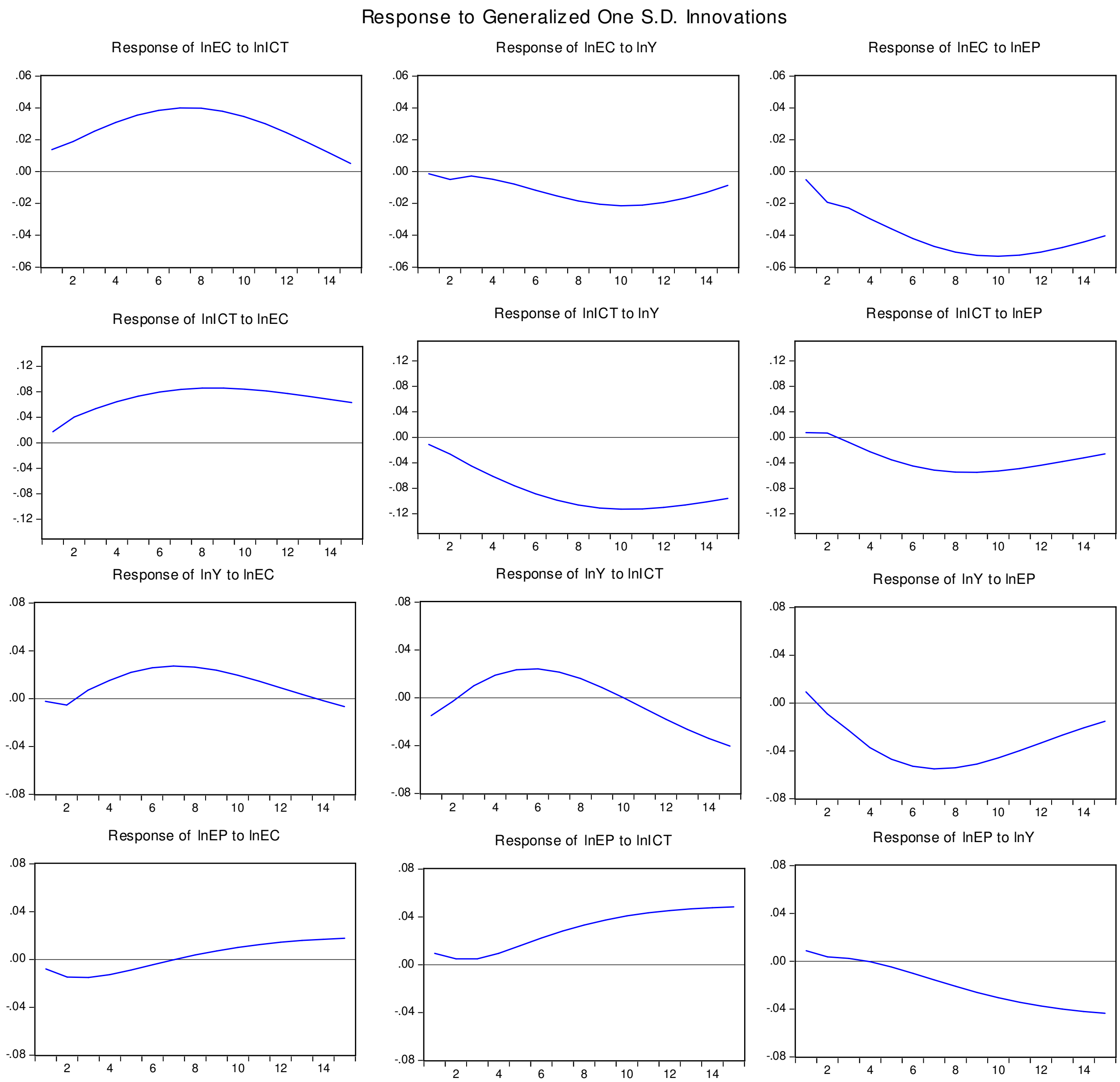
Variance Decomposition of $\ln EC_t$				
Period	$\ln EC_t$	$\ln ICT_t$	$\ln Y_t$	$\ln EP$
1	100.0000	0.0000	0.0000	0.0000
2	88.3568	1.9321	0.1566	9.5543
3	80.1485	4.4808	0.1394	15.2312
4	71.2974	7.2527	0.0966	21.3531
5	63.9256	9.4001	0.0832	26.5909
6	58.0197	10.8002	0.1947	30.9852
7	53.5469	11.5178	0.4626	34.4725
8	50.2335	11.7054	0.8601	37.2008
9	47.8191	11.5140	1.3291	39.3377
10	46.0776	11.0746	1.8078	41.0398
11	44.8308	10.4969	2.2430	42.4291
12	43.9385	9.8740	2.5956	43.5917
13	43.2887	9.2870	2.8431	44.5810
14	42.7897	8.8077	2.9800	45.4224
15	42.3641	8.4989	3.0182	46.1186
Variance Decomposition of $\ln ICT_t$				
Period	$\ln EC_t$	$\ln ICT_t$	$\ln Y_t$	$\ln EP$
1	12.1933	87.8066	0.0000	0.0000
2	20.1653	79.0591	0.7366	0.0388
3	22.1375	73.8935	2.7021	1.2666
4	23.1132	68.9266	4.8728	3.0872
5	23.5442	64.5019	7.0886	4.8652
6	23.7764	60.7104	9.2412	6.2718
7	23.9139	57.5360	11.2900	7.2599
8	24.0060	54.9136	13.2056	7.8746
9	24.0714	52.7687	14.9699	8.1898
10	24.1176	51.0309	16.571	8.2800
11	24.1475	49.6381	18.0035	8.2108
12	24.1618	48.5360	19.2646	8.0375
13	24.1609	47.6775	20.3573	7.8041
14	24.1453	47.0218	21.2885	7.5442
15	24.1159	46.5334	22.0689	7.2815
Variance Decomposition of $\ln Y_t$				
Period	$\ln EC_t$	$\ln ICT_t$	$\ln Y_t$	$\ln EP$
1	0.1110	5.2492	94.6397	0.0000
2	0.4202	2.9054	91.2355	5.4387
3	0.7553	2.6638	82.6852	13.8955
4	2.1805	3.4728	69.1505	25.1965
5	4.3628	4.2959	55.9689	35.3722
6	6.5245	4.6628	45.7023	43.1102

7	8.3096	4.5525	38.6592	48.4784
8	9.6012	4.1721	34.1266	52.0999
9	10.419	3.7936	31.2761	54.5109
10	10.8249	3.6958	29.4427	56.0364
11	10.8939	4.1356	28.1613	56.8091
12	10.7120	5.3117	27.1404	56.8354
13	10.3754	7.3137	26.2339	56.0769
14	9.9831	10.0799	25.4107	54.5260
15	9.6220	13.4004	24.7130	52.2645
Variance Decomposition of $\ln EP$				
Period	$\ln EC_t$	$\ln ICT_t$	$\ln Y_t$	$\ln EP$
1	1.6182	4.3054	3.5459	90.5303
2	4.1640	4.2001	2.5427	89.0930
3	5.9234	4.6802	2.2209	87.1754
4	6.7832	6.2957	1.9854	84.9356
5	6.8086	9.3636	1.7882	82.0394
6	6.3622	13.8661	1.8035	77.9680
7	5.7729	19.3787	2.2519	72.5964
8	5.2789	25.2346	3.2589	66.2273
9	4.9998	30.7762	4.7995	59.4243
10	4.9504	35.5613	6.7313	52.7568
11	5.0830	39.4191	8.8689	46.6287
12	5.3306	42.3851	11.0452	41.2389
13	5.6334	44.6004	13.1390	36.6270
14	5.9491	46.2344	15.0764	32.7400
15	6.2525	47.4426	16.8206	29.4842

Electricity consumption contributes to ICT by 24.11 percent due to one standard shock stemming in Electricity consumption. The share of economic growth (electricity prices) is 22.06 (7.28) percent and rest i.e. 46.53 percent portion of ICT is explained by its own one standard shock.Electricity consumption and ICT contribute to economic growth is 9.62and 13.40 percent respectively. A 24.71 percent of economic growth is explained by own standard shock. The contribution of electricity consumption and economic growth to electricity prices is 6.25and 16.82 percent respectively. The share of ICT to electricity prices is 47.44 percent.

Overall, we find that electricity prices cause electricity consumption. The unidirectional causality is found running from electricity consumption and economic growth to ICT. Economic growth is cause of electricity prices and electricity prices are caused by ICT.

Figure-4: Impulse Response Function



The impulse response function is alternative to variance decomposition method shows how long and to what extent dependent variable reacts to shock stemming in the independent variables (see

Figure-3). The results indicate that the response in electricity consumption due to forecast error stemming in ICT initially rises, goes to peak and then starts to decline after 7th time horizon. This presents an inverted U-shaped between electricity consumption and ICT. The contribution of economic growth and electricity prices to electricity consumption is negative. ICT responds positively but negatively electricity consumption, economic growth and electricity prices (after 3rd time horizon). The response in economic growth is also an inverted U-shaped and same inference is concluded for economic growth and ICT. Electricity prices contribute negatively after 1st time horizon. The response in electricity consumption is positive and negative due to forecast error in electricity consumption (after 8th time horizon), ICT and economic growth (after 4th time horizon).

V. Conclusion and Policy Recommendations

This paper investigated the relationship between information communication and technology, and electricity demand by incorporating electricity prices and economic growth in case of UAE over the period of 1975Q1-2011QIV. We have applied Ng-Perron unit root test to examine the stationarity properties of the variables. The combined cointegration developed by Bayer and Hanck is used to test whether cointegration exists among the series. Our results reveal that variables are cointegrated. ICT adds in electricity consumption. Electricity prices decline electricity demand. Economic growth lowers electricity consumption. The non-linear relationship between ICT and electricity consumption is inverted U-shaped. The causality analysis expose that ICT Granger causes electricity consumption and same is not true from opposite side. Electricity prices Granger causes ICT and economic growth. The bidirectional causal relationship is found between electricity consumption and economic growth.

Our results indicate that electricity consumption is Granger cause of ICT which suggests the deployment of energy efficient technologies and smart ICT infrastructure network grid on urgent basis. Energy efficientICT infrastructure not only lowers energy (electricity) intensity but also saves environment from degradation. The adoption of electricity conservation policies is suitable tool because electricity consumption Granger causes economic growth and in resulting, economic growth Granger causes electricity consumption. Any reduction in electricity supply will not only harm economic growth and electricity demand is also declined as results of decline in economic growth. The causality running from ICT to economic growth further shows the importance to enhance R & D for energy efficient technologies and smart ICT infrastructure in the case of UAE.

Reference

1. Banerjee, A., Dolado, J., and Mestre, R., (1998). Error-Correction Mechanism Tests for Cointegrationin A Single-Equation Framework. Journal of time series analysis, 19(3): 267-283.
2. Barua A. and B. Lee (1997). The information technology productivity paradox revisited: A theoretical and empirical investigation in the manufacturing sector. The International Journal of Flexible Manufacturing Systems 9, 145-166
3. Basu S., J. G. Fernald, N. Oulton, and S. Srinivasan (2003). The Case Of The Missing Productivity Growth, or Does Information Technology Explain Why Productivity Accelerated In The United States But Not In The United Kingdom? NBER Working Paper No. 10010.
4. Bayer, C., and Hanck, C., (2013). Combining Non-CointegrationTests. Journal of Time Series Analysis, 34(1): 83-95.
5. Berndt, Ernst R. and Morrison, Catherine J. (1995). High-tech Capital Formation and Economic Performance in U.S. Manufacturing Industries: An Exploratory Analysis", *Journal of Econometrics* 65: 9-4
6. Biscourp P., B. Crepon, T. Heckel and N. Riedinger (2002). How do firms respond to cheaper computers? Microeconomic evidence for France based on production function approach. Economie et Statistique 8 355-356
7. Chen, X., (1994). Substitution of information for energy: conceptual background, realities and limits. *Energy Policy* 22 (1), 15–27

8. Cho, Y., Lee, J., Kim, T.-Y., 2007. The impact of ICT investment and energy price on industrial electricity demand: dynamic growth model approach. *Energy Policy* 35 (9), 4730–4738
9. Collard, F.,F Feve, P.,Portie,F.,(2005).Electricity consumption and ICT in the French service sector. EnergyEconomics27,541–550.
10. Daly, J. (2003) ICT and Ensuring Environmental Sustainability, Development Gateway Available http://topics.developmentgateway.org
11. Economic Review 91(1), 1-32.
12. Engle, R. F. and Granger, C. W., (1987). Co-Integration and Error Correction: Representation, Estimation, and Testing.Econometrica: Journal of the Econometric Society: 251-276.
13. European Commission e-Business Watch 2008. The implications of ICT for energy consumption, Impact study no. 09/2008.
14. Gordon, Robert J. (2000): Does the “New Economy” Measure up to the Great Inventions of the Past? Journal of Economic Perspectives 14 (4),49–74
15. Hendel I. (1999). Estimating multiple-discrete choice models: An application to computerization returns. The Review of Economic Studies 66(2), 423-446.
16. Hoon Y-S. (2003). Does information technology contributed to economic growth in developing countries? A cross-country analysis. Applied Economics Letters 10 (11), 679-82
17. Johansen, S., (1991). Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models.Econometrica: Journal of the Econometric Society: 1551-1580.
18. Jorgenson D. W. (2001). Information technology and the US economy. American
19. Jorgenson D. W. (2004). Accounting for growth in the information age. Forthcoming in Philippe Aghion and Steven Durlauf eds. Handbook of Economic Growth. Amsterdam, North Holland.
20. Jorgenson D. W., K.J. Stiroh and M.S. Ho (2002). Information technology, education and the sources of economic growth across US industries. Mimeo, April.
21. Jorgenson, Dale W., and Kevin J. Stiroh. (1999). Information Technology and Growth. American Economic Review 89 (2), 109-15.
22. Kanter, J., 2008. The Computer Age and its Carbon Footprint. New York Times
    Koomey, GJ. (2008). Worldwide electricity used in data centers. Environmental ResearchLetters. 3, 034008 (8pp)
23. Ketteni, E., Manumeas, T. and Pashardes, P.(2012). ICT and energy use: patterns of Substitutability and complementarity in production. NEUJOBS WORKING Paper D3.5/December 2012
24. McDermott, J., and McMenamin, P. (2008). *Assessing Inflation Targeting in Latin America with a DSGE Model.*Central Bank of Chile Working Papers, N° 469, Chile.
25. Oliner S. D. and D. E. Sichel (2000). The resurgence of growth in the late 1990s: Is information technology the story? *Journal of Economic Perspectives* 14(4), 3-22
26. Peter Boswijk, H., (1994), “Testing For an Unstable Root In Conditional and Structural Error Correction Models”, Journal of econometrics, 63(1): 37-60.
27. Phillips, P. C., and Ouliaris, S., (1990), “Asymptotic Properties of Residual Based Tests for Cointegration”, Econometrica: Journal of the Econometric Society: 165-193.

28. Romero, A. M., (2005). *Comparative Study: Factors that Affect Foreign Currency Reserves in China and India* 2005). *Honors Projects.* Paper 33, Illinois Wesleyan University, United States.
29. Romm, J., 2002. The Internet and the new energy economy. Resource, Conservation and Recycling 36, 197–210.
30. Røpke, I., Haunstrup C.T., Ole Jensen, J., (2010).Information and communication technologies—a new round of household electrification .*Energy Policy* 38(4),1764–1773.
31. Sadorsky,P. (2012). Information communication technology and electricity consumption in emerging economies, *Energy Policy*, 48 (2012) 130–136
32. Takase, K., Murota, Y., (2004). The impact of IT investment on energy: Japan and US comparison in 2010. Energy Policy 32 (11), 1291–1301.
33. Walker, W., (1985). Information technology and the use of energy. *Energy Policy* 13 (5), 458–476.
34. Walker, W., (1986). Information technology and energy supply. *Energy Policy* 14 (6), 466–488.