

Information and Communication Technology (ICT) and Economic Growth in Iran: Causality Analysis

(*Teknologi Maklumat dan Komunikasi (ICT) dan Pertumbuhan Ekonomi di Iran:
Analisis Kasualiti*)

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ABSTRACT

Iran is currently implementing policy measures to increase the contribution of Information and Communication Technology (ICT) to economic performance. However, little attention is given to examining whether ICT investment contributes to the economic growth of Iran. Concerning the importance of the causal link between these two variables to national policy implications, the present study employs a Granger causality analysis to examine the cause and effect relationship between ICT infrastructure and output growth in a multivariate setting that includes labor and capital variables. The results indicate that a long-run equilibrium relationship exists between ICT development and economic growth. Furthermore, the findings provide evidence of significant uni-directional short-run causality running from economic growth to ICT development in the Iranian economy. In terms of policy implications, the findings support the idea that this relationship is sustainable. However, in the short-run, investing in other important sectors and promoting ICT-use should be a priority for boosting the development of the national economy and ICT.

Keywords: *ICT infrastructure, economicgrowth, causal relationship, Iran's ICT*

ABSTRAK

Iran sedang melaksana langkah-langkah dasar untuk meningkatkan sumbangan Teknologi Maklumat dan Komunikasi (ICT) kepada prestasi ekonomi. Walau bagaimanapun, sedikit perhatian diberi kepada memeriksa sama ada pelaburan ICT menyumbang kepada pertumbuhan ekonomi Iran. Mengenai kepentingan hubungan bersebab antara kedua-dua pembolehubah kepada implikasi dasar negara, kajian ini menggunakan analisis kasualiti Granger untuk mengkaji punca dan kesan hubungan antara infrastruktur ICT dan pertumbuhan keluaran dalam persekitaran multivariat yang termasuk pembolehubah buruh dan modal. Hasil kajian menunjukkan bahawa hubungan keseimbangan jangka panjang wujud di antara pembangunan ICT dan pertumbuhan ekonomi. Tambahan pula, penemuan memberikan bukti penting uni-arah sebab-musabab jangka pendek berlaku daripada pertumbuhan ekonomi kepada pembangunan ICT dalam ekonomi Iran. Dari segi implikasi dasar, penemuan menyokong idea bahawa hubungan ini adalah mampan. Walau bagaimanapun, dalam jangka pendek, pelaburan dalam sector penting yang lain dan menggalakkan penggunaan ICT harus menjadi keutamaan untuk meningkatkan pembangunan ekonomi negara dan ICT.

Kata kunci: *Infrastruktur ICT, pertumbuhan ekonomi, hubungan sebab-musabab, ICT Iran*

INTRODUCTION

Over the past decade, most developing countries have searched for ways to increase their Information and Communications Technology (ICT) infrastructure capacity to enhance the rate of economic growth and to narrow the gap of economic activity with the developed countries. Lee et al. (2005) argue that a developing country may make considerable investments in ICT infrastructure due to the notion that jumping onto the 'ICT bandwagon' accelerates economic growth. However, far too little attention has been given to examining whether ICT investment contributes to the economic prosperity of such countries. Although studies examining developed

economies suggest the strong role of ICT investment in economic growth alongside the existing causal relationship in one or both directions, the conditions in developing economies are different. Therefore, it is desirable for any developing country focusing on ICT development strategy to perform a careful empirical analysis of the causal relationships between ICT development and economic growth.

Since 1995, Iran has witnessed an increase in telecommunication infrastructure capacity and developments in information technology to benefit from ICT contribution. However, two questions arise. Does ICT development lead to economic growth? Is there reverse causality with a direction running from

economic growth to ICT development? Although a few studies in Iran at the firm level show the contribution of ICT to productivity (Gholami et al. 2004; Moshiri & Jahangard 2007), the contribution of ICT to economic growth can be demonstrated by its broader impacts on the whole economy. Considering the significant expansion of the Iranian ICT infrastructure in recent years, a lack of empirical studies exists concerning its causal relationship with economic growth.

The primary purpose of the present study is to empirically examine the cause and effect relationship between ICT development and economic growth in Iran. The motivation for the present study arises from the fact that the direction of causality between ICT and economic growth implies important national policy implications concerning the allocation of restricted resources (e.g., capital and labor) for the purpose of accelerating national economic growth. Accordingly, two principal questions are raised. First, does a long-run steady-state relationship exist between ICT infrastructure and output growth in Iran? Second, given the existence of a cointegrated relationship, what is the direction of causality between the two variables in the short-run? To answer these questions, the present study utilizes a cointegration framework and Granger causality tests to examine the relationship and causality between ICT infrastructure and output growth in a multivariate setting that includes labor and capital.

The remainder of the paper is organized as follows. The next section reviews the empirical works concerning ICT pay offs in economic growth and the direction of causality between them. Section three provides an overview of ICT infrastructure in Iran. Section Four describes the theoretical frame work and is followed by a description of the econometric methodology in Section Five. Then the empirical results, discussion and policy implication; and conclusions are presented in the remaining two sections, respectively.

LITERATURE REVIEW

STUDIES ON ICT DEVELOPMENT AND ECONOMIC GROWTH

ICT refers to technologies that provide access to information through telecommunications and includes telephone services (both fixed line and mobile phones); wireless networks; and other communication mediums, as well as the equipment and services associated with these technologies, such as computers, network hardware and software.

Since the beginning of 1980s, when the information age began, a plethora of research has been undertaken that applies numerous methodologies to evaluate the contribution of ICT to economic prosperity. Although the preliminary studies report little evidence concerning the

contribution of ICT to economic growth and total factor productivity in the 1970s and 1980s in the U.S. economy (Oliner & Sichel 1994; Jorgenson & Stiroh 1995), the ICT contribution to productivity growth is evident during the second half of the 1990s in the U.S. economy (Jorgenson 2001; Jorgenson & Stiroh 2000). Furthermore, several studies (e.g., Oliner & Sichel 2000, 2002; Baily & Lawrence 2001; Jorgenson et al. 2004, 2007) reveal that the effect of ICT-use on other industries (i.e., capital deepening) is more effective than ICT production itself.

Alongside the studies that examine the U.S., other research examines the contribution of ICT to economic growth and total factor productivity by considering individual countries or groups of countries. Most studies in developed and industrialized countries report that ICT plays a key role in economic performance during the second half of the 90s, such as Niininen (2001) and Jalava and Pohjola (2005, 2007) in the context of Finland; Oulton (2002) in the context of the U.K.; the Rhine-Westphalia Institute and Gordon (2002) in the context of Germany; Gretton et al. (2002) and Simon and Wardrop (2002) in the context of Australia; Kegels et al. (2002) in the context of Belgium; Miyagawa et al. (2002) in the context of Japan; Armstrong et al. (2002) and Khan and Santos (2002) in the context of Canada; Cette et al. (2002) in the context of France; Van der Wiel (2002) in the context of the Netherlands; and Kim (2002) in the context of South Korea. In general, such studies imply that a clear and positive link exists between ICT development and economic growth, but the link takes a long time to become visible at the macroeconomic level. ICT capital growth accelerates productivity growth, but with long lags between 5-15 years (Basu & Fernald 2007).

From another perspective, the relationship between ICT and economic performance can be examined through the use of cross-country comparisons that generally magnify the gap between developed economies and developing economies. Extant studies comparing OECD countries show that the contribution of ICT to economic growth in the U.S. and Canada is larger than other countries (e.g., Daveri 2000, 2002; Colecchia & Schreyer 2001). Meanwhile, studies comparing economic growth among European Union countries find that the contribution of ICT among these countries varies (e.g., Van Ark et al. 2002; Timmer et al. 2003). On the other hand, comparative studies between developed and developing countries indicate that, in contrast to developed countries, developing countries do not experience significant returns from ICT development (see Dewan & Kraemer 2000; Pohjola 2001). At the same time, the results of studies focusing only on developing economies consistently report the limited impact of ICT development on economic growth (e.g., Avgerou 1998 and Wang 1999 in the case of Taiwan; Meng & Li 2002 in the case of China). In the Middle East, Nour (2002)

uses data from Egypt and other Persian Gulf countries and reports that the correlation between ICT development and economic growth is positive, but not significant. However, unlike most developing countries, East Asian and South East Asian countries benefit from ICT in regards to their economic and social development (Jussawalla & Taylor 2003). According to Kuppusamy et al. (2008), ICT investment has a positive and significant long-run relationship with economic growth in Australia, Malaysia and Singapore.

Piatkowski (2002) claims that ICT investment in less-developed countries is not at sufficient levels to assess the impact of ICT investment on output growth in such growth. Therefore, the role of the ICT investment in developing countries is not clear due to a lack of capital investment; related knowledge; and the existing lag regarding ICT diffusion (Meng & Li 2002). Elsewhere, Lee et al. (2005) suggest that a threshold of ICT capital must be attained before the effect of ICT on output growth becomes measurable. Thus, Lee et al. (2005) suggest that developing countries should promote the use of ICT and provide the necessary environmental conditions to sustain the effective use of ICT. Furthermore, Grace et al. (2003) add that some less-developed countries are in danger of falling into a poverty trap in the event that findings concerning ICT threshold effects hold true (i.e., if the development of ICT is related to the income level and if income growth is affected by a threshold of ICT capital, then low-income countries are less likely to benefit from the opportunities provided by ICT development).

Based upon the review of the abovementioned literature, four conclusions can be drawn. First, the ICT contribution gap is evident among countries. The ICT contribution to economic growth and total productivity growth in the U.S. and Canada is more than other countries, while the ICT contribution has been more sporadic in Europe. With the exception of newly industrialized countries in South East Asia, developing countries are apparently unable to take advantage of ICT in order to accelerate the rate of output growth and productivity in their countries. Second, despite the general view of ICT contribution to developed economies, a lag between the investment in ICT and its impact on the whole economy is evident in such economies. In other words, the effect of ICT on GDP or productivity takes a long time to become visible. Third, some studies find that the most positive impact of ICT on growth is not straightforward as initially perceived, particularly since it is reported that the effect of ICT-use on other industries (capital deepening) is more effective than ICT production itself. However, the length of lag and how long it takes for spillovers to occur is not clear. Finally, the contribution of ICT is visible when a significant threshold ICT capital is achieved. The various results from different countries and regions maintain the debate on the contribution of ICT to economic growth (Qiang et al. 2004).

CAUSAL ANALYSIS STUDIES ON ICT DEVELOPMENT AND ECONOMIC GROWTH

The previous portion of the literature review focuses on the relationship between ICT development and economic growth without considering the direction of causality. Causality studies target the link between ICT development and economic growth by investigating the existence of causal relationships and the direction of causality. Moreover, the importance of reverse causality is due to the fact that a bilateral relationship exists between better communication systems and higher income (i.e., better communication systems lead to higher incomes and higher incomes, in turn, improve communication systems).

A preliminary work examining causality between ICT development and economic growth by Cronin et al. (1991) reports the existence of a bi-directional causal relationship between ICT development and economic growth in the U.S. economy. Later studies also confirm this bi-directional causal relationship (see Cronin et al. 1993a). Another study suggests that investment in telecommunications infrastructure in the U.S. is causally related to the total factor productivity in the U.S. (Cronin et al. 1993b). However, two causality analysis studies of the U.S. economy that employ the same data set (over the period of 1947–1996) obtain different results. The Granger-Sims causality test employed by Beil et al. (2005) confirms that economic output causes telecommunication investment, but investment by telecommunication firms does not cause output. In contrast, Wolde-Rufael (2007), who uses another version of the Granger causality test proposed by Toda and Yamamoto (1995), finds that bi-directional causality between the two variables exists.

An earlier cross-country study (Madden & Savage, 1998) employing causality tests also reports a bi-directional relationship between ICT development and economic growth in Central and Eastern Europe countries. In a further study based upon panel of data for 30 countries (15 industrialized and 15 developing countries), Dutta (2001) generally confirms both directions of causality, but the causality direction running from ICT infrastructure to economic activity is stronger than the opposite causality direction. Datta and Mbarika (2006) report evidence of causality running from ICT infrastructure to service-sector growth based upon a panel of data for 90 countries that are equally ordered into low-income, middle-income and high-income groups.

One of the most significant current discussions concerning the causal relationship between ICT development and economic growth is that bi-directional or uni-directional causality depends upon the level of income, ICT infrastructure and other factors. A large-scale study that examines the causality for 105 countries (Shiu & Lam 2008a) reveals bi-directional causality in high-income level and European countries, but uni-directional causality in countries with lower income levels that runs from economic growth to ICT development. Shiu and Lam

(2008a) suggest that less-developed countries should create the environmental conditions called ‘critical mass’ by promoting greater ICT penetration rates. In another study, Lam and Shiu (2010) confirm their previous results by assessing the impact of mobile telecommunications on economic growth. Chakraborty and Nandi (2003) utilize panel data of 12 Asian developing countries divided into two categories: high degree of privatization and low degree of privatization. The study finds that causality is bi-directional only for the high degree of privatization group, but ICT development led economic growth for the other group. Chakraborty and Nandi (2011) use a panel of 93 different countries from Asia, Europe, Latin-America and Africa and the findings suggest that ICT infrastructure (Mainline tele density) and per capita growth strongly reinforce each other in the case of relatively less-developed countries in contrast to the findings for relatively developed countries. As a result, various factors in each country may determine the causality and its direction between ICT and output growth, such as the level of development; income; ICT penetration rate; and the degree of privatization.

Nonetheless, the reverse causality issues in the causal relationship between ICT development and economic growth is not straightforward to address. For example, Yoo and Kwak (2004) find a bi-directional causal relationship in South Korea, while Cieslik and Kaniewsk (2004) report that causality runs from ICT infrastructure to income at the regional level in Poland. Meanwhile, Shiu and Lam (2008b) identify the existence of one-way direction from economic growth to ICT development in China. Elsewhere, Veeramacheneni et al. (2007), in a study based on a data panel of ten Latin American countries, find that seven out of ten countries have bi-directional Granger causality in the short-run; two other countries have causality running from economic growth to ICT; and causality runs from ICT to economic growth for the final country. Lee and Becker (2011) and Lee (2011) examine European Union member countries and three Northeast Asian countries (China, Japan and South Korea), respectively. The findings of the two studies indicate that the Granger causality test does not support the causality direction from ICT to growth in the short-run. As a whole, the findings of causality analyses in current empirical studies differ among different countries, which support the idea that special conditions in each country influence the results of the causality direction between ICT and economic growth.

The mixed results from extant empirical causality studies indicate bi-directional, uni-directional or non-causal relationships between ICT development and economic growth. In more developed countries and regions with a higher level of income and ICT infrastructure, bi-directional causality is generally evident. Moreover, some findings indicate that the direction of causality depends upon various factors in each country, including the level of income; ICT

infrastructure; and privatization. However, the issue of the causal direction between ICT and output growth in less-developed countries is still debated. Thus, it is desirable for any developing country with an ICT development strategy to perform a careful empirical causality analysis since the results of the causality test can assist national planners in creating policies regarding the allocation of restricted resources to enhance economic growth. On the assumption that empirical evidence supports causality running from ICT infrastructure to economic growth, then resources should be allocated to the ICT-industry sector. Meanwhile, if causality evidence indicates that causality runs in the opposite direction, more resources should be allocated to other industries to enhance economic growth so that the ICT-industry sector is able to benefit from economic growth.

OVERVIEW OF ICT IN IRAN

The economy of Iran, which is a transition economy, is known as a resource and labor rich economy in the Middle East with a large public sector and more than 80 percent of annual foreign-exchange revenue is dominated by oil and gas exports. Since the early 1990s, government economic policies have resulted in the privatization and opening up of certain sectors of the economy due to a decreased dependency on oil revenues. Although Iran has enjoyed economic growth since the late 1990s, high levels of inflation, low levels of foreign investment and unemployment have impeded the economic performance of the country. Because of this economic challenge, economic growth in Iran decreased after 2009, and according to the United Nation Economic and Social Commission for Asia and the Pacific (UNESCAP) (2012), Iran is expected to experience a lower growth rate of 3% in 2012 following the global economic downturn, unstable oil prices and economic sanctions related to the country’s nuclear program.

The first attempt for ICT development in Iran dates back to the 1960s and 1970s when Iran was a key hub for Information Technology (IT) in the Middle East, due to the presence of foreign software and IT suppliers such as International Business Machines (IBM) (Nicholson & Sahay 2003). However, after the revolution in 1979 and following the Iran-Iraq War (1980-1988), which significantly caused economic damage, the situation changed dramatically until the late 1990s. Following efforts towards economic liberalization, privatization and competition in the telecommunication market became the main ICT themes of the third national development plan of Iran (2000-2004).

Pursuant to the development plan, the ICT infrastructure capacity in Iran developed dramatically and, despite the restrictions imposed by Article 44 of the Constitution, a variety of investment options were opened to the private and public sectors. Service provision in

data communications, the internet access and satellite communications are salient examples of such investment opportunities. According to Nicholson and Sahay (2003), the market liberalization and emphasis upon ICT were due to the fact that Iran needed to determine alternative strategies to its dependence on oil revenues.

Furthermore, the Supreme Council of Information & Communication Technology (SCICT), the highest decision-making body in the area of ICT policy-making in Iran, laid the foundations for the national ICT agenda ‘TAKFA’ (an acronym in Persian that means development of the information technology applications program,) as a road to knowledge-based development in Iran. The TAKFA project was launched by the Iranian government in July 2002 and succeeded in making ICT an important aspect of the national agenda and influenced major policy makers to make further investments in ICT infrastructure. ICT became the core of Iran’s fourth national development plan (2005-2009), as well as the most vital development strategy. The following are key elements of the Iranian government’s policy regarding the telecommunication sector:

1. Migration from monopoly to competition in telecom industry;
2. Telecom de-regulation;
3. Migration from traditional telecom to Next Generation Network (NGN);
4. Promotion foreign investment.

The objective of the policy was to provide 40 million telephone lines; 30 million mobile lines; and 20 million Internet access accounts by the end of Iran’s fourth national development plan (2005-2009).

As a result, the implementation of the third and fourth national plans regarding the capacity of ICT infrastructure dramatically increased. According to the databases of the International Telecommunications Union (ITU) (2011), the number of fixed-line subscribers reached 25.80 million with a penetration rate of 34.8 in 2009; and the

mobile penetration rate increased from 1.44% in 2000 to 71% in 2009 with a total of over 52.5 million subscribers (almost 100 percent of the population of Iran). The mobile penetration rate was more than 91% in 2010, and the percentage of population covered by mobile cellular network was 95% in 2009. Meanwhile, this indicator for upper-middle income groups; and the Middle East and North Africa regions was 94% and 93%, respectively in 2009 (World Bank 2012).

The number of personal computers and internet users per 100 inhabitants is used to capture IT penetration. Since 2000, with the rapid penetration of IT, full internet service is available in all major cities. Internet access is also increasing rapidly in small towns and villages. However, the number of Internet users only increased from 0.625 million to more than 8.2 million (ITU 2011) between early 2000 and 2009, which is considerably less than fourth national development plan envisioned. A major obstacle in Iran is the low speed and high cost of providing Internet access, while easy access to a cheap, confident and high-speed Internet are the primary objectives of Iran’s national ICT development plan. In addition, the penetration of personal computers increased from 6.3% in 2000 to 10.2% in 2009, compared to 11.2% and 5.7% (in 2009) for upper-middle income groups; and the Middle East and North Africa regions, respectively (World Bank 2012).

Despite the high rate of investment by the Iranian government (from 6% in 2000 to 74.5% in 2009), the ICT sector accounted for only 1.4 percent of the Iranian GDP (in 2009) compared to 3.1% for Middle East and North Africa regions, which implies the minor role played by ICT in the Iranian economy. On the other hand, government policies restricted computer and software imports and, as a result of this policy, the import of ICT goods reduced from 5.5% in 2000 to 1.9% in 2009. However, Iranian ICT companies have been enabled to make improvements in the production of software and key IT components. Such companies now have the

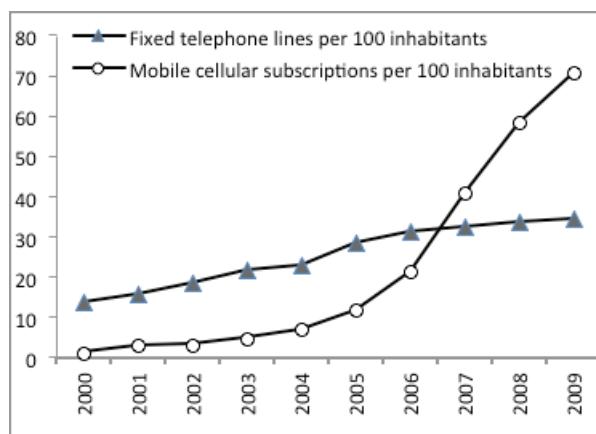


FIGURE 1. Penetration Rate of Fixed-Line and Mobile Phone (source: ITU)

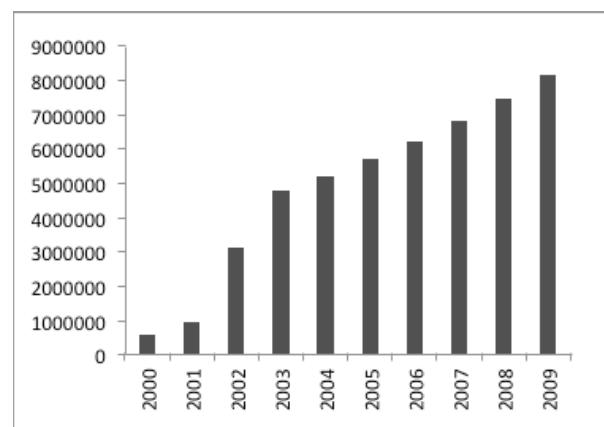


FIGURE 2. Number of the Internet users (source: ITU)

TABLE 1. Telecommunication Sector Efficiency and Capacity

	IRAN		Upper-middle income group	Middle East & North Africa Region
	2000	2009	2009	2009
Telecommunications revenue (% of GDP)	1.1	1.4	3.3	3.1
Telecommunications investment (% of revenue)	6	74.5	18	23.6
ICT goods exports (% of total goods exports)	0	0.1	12.2	
ICT goods imports (% of total goods imports)	5.5	1.9	15.1	

Source: World Bank

potential to manufacture a variety of software, as well as manufacture computers; and provide internet access and IT components for the domestic market.

The most important priorities relating to ICT development in the fifth national development plan (2010-2014) include the provision of high-speed internet ports (50% households); providing machine and business electronic services to the general population (70% of services); replacing money and near-money payments with electronic payments (80% of transactions); building e-health profiles (100% of the population); forming national intelligent cards as a base for e-government systems (100% of the population); developing electronic education (Tele-education) platforms (30% education services); the development of e-commerce both nationally (20% of national trades) and internationally (30% of Iran's international trade); and the development of information technology products and service export (1.5% of non-oil exports).

A wide digital divide continues to exist between the global average according to the ICT index and that of Iran despite the fact that major steps are being taken towards ICT infrastructure development. Iran is only ranked 94 among 146 countries (World Bank 2012). In recent years, numerous obstacles have prevented investments in ICT from enabling economic and social development. The most important relates to the unsustainable situation of privatization and liberalization in the Iran economy, which does not favor an open market and privatization in ICT sector. Furthermore, foreigners are prevented from owning majority shares in telecom companies by regulatory and legal barriers. Finally, unfair economic sanctions against Iran block the flow of technology and foreign investment.

Iran, as a developing country with a number of significant economic challenges, is attempting to enjoy the contribution of ICT development. To achieve a desirable status, significant improvements to fixed lines, mobile phones, PC penetration and number of Internet hosts are required. A well-developed ICT infrastructure can play a key role in the economic growth and development of a country, but in the case of Iran, particularly in relation to the abovementioned obstacles, the present study seeks to answer whether the current

level of development in ICT contributes to the economic growth of Iran. Here, the empirical evidence causality test is utilized to enable the determination of the cause and effect relationship between ICT development and economic growth in Iran.

THE THEORETICAL FRAMEWORK

In order to examine the contributions of ICT to economic growth, most extant empirical studies at the macro level utilize the production function and the growth accounting approach with ICT as an explanatory variable. This approach, which is based upon the works of Solow (1957) and Jorgenson (1966), considers the aggregate production function in the form of the production possibility frontier. The basic production function is extended to take into account the technological progress, embodied in the form of ICT capital and non-ICT capital. Therefore, the typical production function for examining the impact of ICT on output requires three resources: labor, ICT capital and other capitals. If production is assumed to follow a Cobb-Douglas function form, the following production function is utilized:

$$Y = A \text{ICT}^{\beta_1} K^{\beta_2} L^{\beta_3} \quad (1)$$

where Y is output (GDP), ICT denotes ICT capital, K denotes other capitals, and L denotes labor force. A is a constant representing other factors of production, and β_1 , β_2 , and β_3 are the elasticities of the production resources.

In function(1), ICT is modeled as a special form of capital to estimate its impact on output growth. The function can be converted into the following log-linear form for analytical convenience:

$$\ln Y = \ln A + \beta_1 \ln \text{ICT} + \beta_2 \ln K + \beta_3 \ln L \quad (2)$$

Based upon extant literature, the effect of ICT development on economic growth can be estimated from Equation (2) by using time-series methodology within a country or cross section data across countries. In such a model, output is caused by changes in the ICT and non-ICT capital stock and other inputs (such as

labor and technology). However, the regression result from Equation (2) does not necessarily imply causation. In this respect, as an alternative to the aforementioned approach, the causality testing framework can be applied for examining the causal relationship between ICT and economic growth.

The concept of 'causality test' was first introduced by Granger (1969) and has been extensively used in empirical analyses to detect the direction of causality between any two variables. Granger (1988) states that a dynamic causal relationship between two variables is a prerequisite for determining the existence of a long-run equilibrium relationship. Thus, the causality between any two variables can be determined by examining the way they move with respect to each other over time (Granger 1969).

To test for Granger-causality between output and ICT, two bivariate models are specified. Corresponding to the stationary time series data of Y and ICT, the Granger-causality test is specified as follows:

$$Y_t = \sum_{i=1}^n a_i Y_{t-i} + \sum_{i=1}^l b_i ICT_{t-i} + \sum_{i=1}^m c_i Z_{t-i} + u_t \quad (3)$$

$$ICT_t = \sum_{i=1}^p d_i ICT_{t-i} + \sum_{i=1}^q e_i Y_{t-i} + \sum_{i=1}^r g_i Z_{t-i} + v_t \quad (4)$$

The basic concept behind model (3) is that ICT capital is a Granger cause of economic output ($ICT \rightarrow Y$). The assumption is made that ICT investment plays a key role in output growth of an economy. In addition, in model (4), economic output causes ICT capital in the Granger sense ($Y \rightarrow ICT$). In this case, the output growth of an economy plays a key role in enhancing ICT development.

In functions (3) and (4), Z stands for an additional or controlling variable, such as labor and physical capital, human capital, foreign investment and openness. In the empirical causality literature reviewed above, some representative examples of causality testing between ICT and growth are examined by a wide variety of control variables of interest. Within this literature, however, many studies do not specify a Granger causality model by including additional or controlling variables. As a result, other factors in model specifications are not fully considered (e.g. Chakraborty & Nandi 2003; Beil et al. 2005; Wolde-Rufael 2007; Shiu & Lam 2008a b; Lam & Shiu 2010; Lee & Becker 2011; and Chakraborty & Nandi 2011). Moreover, Granger causality analysis is a part of the Vector Autoregression (VAR) model applying a causality testing framework that includes cointegration tests, error correction mechanisms, variance decomposition and Impulse Response analysis. This methodological approach removes the spurious regression problem in examining the causation between variables by using time series techniques.

METHODOLOGY AND DATA

METHODOLOGY

The procedure for estimation begins with a unit root test to investigate the order of integration of time series. Two standard tests are performed based on the work of Dickey and Fuller (1979) and Phillips and Perron (1988). Moreover, cointegration analysis is performed to determine the existence of any long-run relationship between the variables in the case that the time series show integration of the same order (more than zero). Cointegration analysis is investigated using the Juselius-Johansen approach (Johansen 1988; Johansen & Juselius 1990). The results of the cointegration analysis will define the methodology to be followed during the causality analysis. In general, the Granger (1969, 1986, 1988) causality test involves Vector Autoregression (VAR) models in the absence of cointegration, while the Vector Error Correction Model (VECM) is applicable to estimation if cointegration is present. In addition, the VECM approach allows for the determination of the direction of causality among variables in both the short-run and the long-run. Furthermore, Variance Decompositions (VDCs) and Impulse Response Functions (IRFs) analyses are applied as an indicator of the dynamic properties of the system and the degree of exogeneity among the variables beyond the sample period, while VECM can only indicate the Granger causality within the sample period. These tools investigate how a variable responds to unit standard error shock in other variables and determines the proportion of the forecast error variance of a variable due to innovations of other variables at different forecast horizons. Remarkably, the result of both analyses is roughly the same.

DATA

Annual data from 1975 to 2009 (35 observations) are used according to their yearly time-series availability. Following previous empirical studies (Röller & Waverman 1996, 2001; Chakraborty & Nandi 2003, 2011; Shiu & Lam 2008a, 2008b; Lam & Shiu 2010), the data of Teledensity is applied as a proxy for ICT infrastructure. Teledensity refers to the total number of fixed-line and mobile phone subscribers per 100 persons. Data concerning Teledensity is obtained from the databases of the ITU. Chakraborty and Nandi (2003) theorize that Teledensity is a good proxy to reflect ICT development due its ability to measure the stock of telecommunications infrastructure. Moreover, Teledensity indices are measured universally and collected by international agencies; and the longitudinal data availability corresponds well with that of real GDP (Lee & Becker 2011). Data concerning other time series variables are obtained from the World Bank (World

Development Indicators), including information relating to economic output (Y); labor (L); capital (K); the data of Real GDP; labor force; and Gross Fixed Capital formation.

EMPRICAL RESULTS

The present study applies two standard tests in order to check the unit roots of the time series variables: the Augmented Dickey-Fuller (ADF) test and the Phillips-Perron (PP) test.

The results of the unit-root tests are presented in Table 2. The results indicate that at the levels of all series (real GDP (Y), Teledensity, labor (L) and capital (K)), the null hypothesis that the series are non-stationary is not rejected. However, after first differencing, no evidence is found that the variables are non-stationary. This is confirmed by the fact that the null hypothesis is rejected in favor of the alternative hypothesis that the series are stationary when the first difference of the variables is obtained. Hence, all series are integrated of order 1, I(1).

Having confirmed the existence of unit roots for all series, Cointegration and error correction mechanisms are used alongside the Granger causality test to examine the relationships between real GDP (Y), Teledensity, labor (L) and capital (K).

Table 3 demonstrates the results of the ‘Trace’ test and the ‘Maximum Eigenvalue’ test, which are two separate tests of Johansen’s cointegration method. The results suggest that these four variables are bound together by long-run equilibrium relationships. Trace statistics indicate two cointegrating vectors at the 1%

level of significance; and one cointegrating vector at the 5% level of significance. Meanwhile the Maximum Eigenvalue statistics indicate one cointegrating vector at the 1% level of significance; and two cointegrating vectors at the 5% level of significance. Consequently, the results of the Johansen’s multivariate cointegration tests provide evidence that three cointegrating vectors exist at the two levels of significance. In other words, a force of equilibrium exists that keeps ICT development, economic growth, labor growth and capital growth together in the long-run.

A significant outcome of this technique is that once the variables are cointegrated, the possibility of spurious estimation is ruled out and at least one channel of Granger causality between variables is active in either the short-run or the long-run.

Although the results of the cointegration tests imply the presence of causality between the variables, the results cannot identify the direction of Granger causality between the variables. Due to the results of the cointegration analysis in this case, as mentioned previously, the Granger causality must be captured using the VECM approach. According to this technique, the chi-squared statistics of coefficients on the lagged endogenous variables resulting from the Block Exogeneity Wald test indicate the existence of short-run Granger causality. On the other hand, long-run causality is implied through the significance of the t-statistics of the lagged error correction terms (ECT_{t-1}), which contain the long-run information since the coefficients are derived from long-run cointegrating relationships. However, the ECT_{t-1} coefficient is a short-run adjustment coefficient indicating

TABLE 2. Tests of the Unit Root Hypothesis

Variables	Aug Dickey-Fuller test		Phillips-Perron test	
	levels	First differences	levels	First differences
Y	1.117	-4.259***	1.201	-4.016***
Teledensity	2.387	-4.680***	6.748	-7.230***
L	0.285	-3.165**	0.122	-3.329**
K	-0.550	-4.502***	-0.497	-4.486***

Note: The optimal lag is automatically selected based on the Schwarz Info Criterion (SIC) for Fisher-ADF regressions. For the Fisher-PP tests, estimators based on kernel-based sums of the covariances are used to correct for autocorrelation. *** and ** denote the rejection of the null hypothesis of non-stationarity at the 1% and 5% levels of significance, respectively.

TABLE 3. Results of the Johansen Cointegration Tests

H_0	H_1	Trace Statistic	Max-Eigenvalue Statistic
$r = 0$	$r > 0$	88.688***	47.418***
$r \leq 1$	$r > 1$	41.270***	25.396**
$r \leq 2$	$r > 2$	15.874**	15.874**
$r \leq 3$	$r > 3$	0.000	0.000

Note: r indicates the number of cointegrating vector. *** and ** indicate significance at the 1% and 5% levels of significance, respectively.

the proportion by which the long-run disequilibrium in the dependent variable is being corrected in each short period (Masih & Masih, 1996).

The empirical results of the estimated VECM are presented in Table 4. Based upon the results, the null hypothesis of no causation running from Teledensity to Y (real GDP) cannot be rejected; while, the null hypothesis of no causation running from Y (real GDP) to Teledensity can be rejected at the 10% significance level. The results of chi-squared statistics of Teledensity and Y coefficients indicate that a uni-directional causal relationship exists from output growth to ICT development in the short-run. Results are consistent with different lag selections, but the

numeric values of the results of different lag selections are not reported.

While the VECM analysis determines the exogeneity or endogeneity of variables and the direction of Granger causality within the sample period, the VDCS can be considered as an out-of-sample causality test. VDCS measure the contribution of each shock in the system that reveals how the behavior of a variable is affected by its own shocks versus shocks to other variables. The VDC analyses presented in Table 7 confirms the conclusion obtained from the sample VECM analysis. After 10 years, 55% of the forecast error variance of real GDP (Y) and 17% of the forecast error variance of Teledensity

TABLE 4. Granger Causality Results Based on Vector Error-Correction Model (VECM)

Dep. Variable	ΔY	Δ Teledensity	ΔL	ΔK			
	chi-squared statistics				$\varepsilon_1(\text{ECT}_{t-1})$	$\varepsilon_2(\text{ECT}_{t-1})$	$\varepsilon_3(\text{ECT}_{t-1})$
ΔY	-	1.076	3.332	0.208	-0.764***	-0.019	0.074
Δ Teledensity	4.775*	-	5.363*	0.672	0.402**	0.874***	0.108
ΔL	5.212*	7.811**	-	1.894	0.035	0.018	-0.024
ΔK	17.118***	3.476	4.105	-	-0.001**	-1.308**	-0.518***

The variables are in first differences (denoted by Δ) of natural logarithms with the exception of the lagged error-correction terms (ECT_{t-1}) generated from Johansen order of cointegration tests conducted in Table 3. The ECTs are derived by normalizing the three cointegrating vectors on Y, thereby resulting in three sets of residuals (ε_1 , ε_2 and ε_3). Diagnostic tests (not reported) conducted for various orders of serial correlation, heteroskedasticity, functional form, and normality are found to be satisfactory. ***, ** and * indicate significance at the 1%, 5% and 10% levels of significance, respectively.

TABLE 5. Variance Decompositions

a: Variance Decomposition of Y (real GDP):				
Period	ΔY	ΔL	ΔK	Δ Teledensity
1	100.000	0.000	0.000	0.000
2	89.320	8.085	1.739	0.856
3	82.049	7.320	8.558	2.073
4	73.626	9.567	10.682	6.125
5	68.594	12.263	11.143	8.000
6	66.029	13.916	11.210	8.845
7	65.833	13.911	11.332	8.924
8	63.964	16.621	10.848	8.567
9	59.129	22.843	9.9539	8.074
10	55.244	27.870	9.299	7.587

b: Variance Decomposition of Teledensity:				
Period	ΔY	ΔL	ΔK	Δ Teledensity
1	2.987	23.767	15.054	58.191
2	9.757	33.371	21.514	35.358
3	15.158	28.023	22.094	34.725
4	20.292	22.909	25.741	31.057
5	20.718	23.363	26.874	29.045
6	18.666	29.394	25.798	26.142
7	17.908	35.807	23.024	23.261
8	19.857	38.926	20.462	20.755
9	21.980	40.448	18.675	18.897
10	22.283	42.691	17.592	17.434

The variables are in first differences (denoted by Δ) of natural logarithms. Figures in the first column (period) refer to the number of the year. All other figures are the Percentage of Forecast Variance Explained by (a) Innovations in real GDP and (b) Teledensity

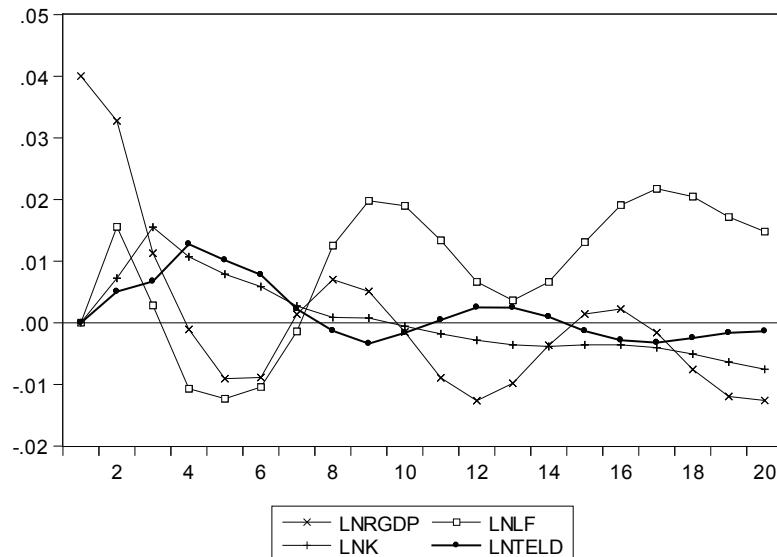


FIGURE 3. Impulse Responses of Real GDP from a One-standard Deviation Shock to Real GDP (LNRGDP), Teledensity (LNTELD), Labor (LNLF) and Capital (LNK).

are explained by their own shocks, which indicate that those variables are relatively endogenous. Moreover, Teledensity is more endogenous than real GDP, which also confirms the result of the short-run Granger causality test.

In addition, the Impulse Response Functions (IRFs) analyses essentially map out the responsiveness of Real GDP to shocks to all four variables, which are presented in Figure 3. The findings show that real GDP positively responds to one standard deviation shock in Teledensity, which gradually stabilizes. Therefore, the IRF analyses appear to be consistent with the results that a long-run equilibrium exists between real GDP and Teledensity in the Iranian economy.

POLICY IMPLICATIONS

In regards to the policy implications resulting from the findings of the present study, the proven existence of a long-run equilibrium relationship between ICT development and economic growth supports the idea that the contribution of ICT to economic growth can be a sustainable phenomenon. In this respect, the upgrading and extension of the ICT infrastructure should be a basic objective for policy-makers as a strategy towards advanced development in the long-run. However, the research findings also shed light on the status of unidirectional causality that runs from economic growth to ICT development in the short-run, unlike extant literature that supports the existence of bi-directional relationships in the context of developed economies. This implies that during the short-run, when ICT development is most affected by economic growth, more resources should be allocated to other important sectors to enhance Iran's

national economy so that the ICT sector can benefit from economic growth. Furthermore, it can be inferred that ICT infrastructure development alone is not enough to stimulate economic growth in Iran. More likely, the underdevelopment of other complementary factors may be a potential reason for this lack of a causal relationship running from ICT development to economic growth in the short-run.

In the case of Iran, the potential complementary factors include policies concerning open markets, privatization and competition in the ICT market that is intended to be monopolized. Another complementary factor relates to the regulatory authority, which requires taking a strong position to support competition in the ICT market. Furthermore, a change in foreign investment policy is needed to increase investment in the ICT infrastructure to reach the necessary threshold of ICT capital. As proposed by Vu (2011), all countries need a more strategic concentration on improving ICT penetration as a key source of economic growth. Improving ICT penetration is dependent upon the upgrading of the ICT infrastructure; reducing the costs of ICT-use; and increasing the long term effects of ICT penetration on economic growth.

Alongside the major complementary factors mentioned above relating to the development of ICT infrastructures, other complementary factors are important for the best use of ICT to generate income. These factors include a good business environment; the reorganization of manual processes; better training of the workforce; and adaptive business models. In the absence of a parallel development in use of ICT established by government policies in Iran, the potential gains from ICT infrastructure development will be limited. As proposed by Lee et al. (2005), developing countries can likely

achieve positive and significant ICT returns by creating the environmental conditions necessary to support the effective use of ICT.

However, the concept of ICT-use goes beyond increasing the penetration of personal computer and internet users. The main problem in Iran arises from inadequate experience in developing and managing in the field of ICT use (i.e., ICT application in commerce, learning, health, and government services needs essential reforms in conventional paradigms and a new vision of the ICT concept). Therefore, it is likely that such environmental conditions will improve the ability to achieve a high contribution of ICT to total output and a strong relationship between ICT development and economic growth in Iran.

CONCLUSION

This study examines the causal relationship between ICT development and economic growth in Iran. To do this, cointegration and error-correction modeling techniques; and Granger causality tests are employed to examine the relationship and causality between ICT infrastructure and output growth in a multivariate setting that includes labor and capital over the period of 1975 to 2009.

The results of estimation indicate that a long-run equilibrium relationship exists between ICT infrastructure and output growth. However, the results do not support short-run significant causality from ICT to output growth. Instead, the results provide evidence of an opposite and significant causality relationship. In terms of policy making, the empirical evidence concerning the existence of a long-run relationship between ICT development and economic growth supports the idea that the phenomenon is sustainable. However, in light of findings indicating that ICT development is affected by economic growth in the short-run, investments in other non-ICT sectors should be of importance for enhancing economic growth and the ICT sector.

In addition, the findings that address the problem of cause and effect feedback causality in the short-run imply that an improvement in ICT infrastructure alone is not sufficient for stimulating growth. Economic growth involves complicated relationships among many variables. Consequently, other complementary factors, such as open markets, privatization and competition in the ICT market, and the implementation of policies that attract an inflow of foreign investments are required to enhance the contribution of ICT development to economic growth. On the other hand, promoting ICT-use and creating the environmental conditions necessary to support the effective use of ICT can likely improve the ability to achieve a higher contribution of ICT development to economic growth.

The present study can serve as a platform for future policy implication efforts attempting to reveal causal

linkages between ICT development and economic growth in the Iranian economy. The results, nonetheless, should be treated with caution for two reasons. First, the causality analysis, although preformed in a multivariate setting by including labor and capital, can be extended to other multivariate settings and include other economic factors, such as human capital, openness, foreign investment and privatization. Second, limitations can exist for studies examining ICT issues in developing countries due to the availability of ICT data. The lack of sufficient data, both qualitative and quantitative in nature, is a common problem in developing countries, which reflects the current level of development in Iran.

Further research should incorporate other relevant variables as determinants of economic growth in the Iran in order to re-examine the cointegrating and causal relationships with real GDP by using more ICT related variables. While such a task will be time-consuming, the results will provide a better understanding of the patterns of causal relationships between ICT development and economic growth. Nonetheless, the present study contributes to literature concerning ICT development and economic growth research in Iran. Furthermore, the present study provides a useful groundwork for causality analyses and policy making, even though it could prove inadequate in demonstrating the full effects of ICT on economic growth in Iran.

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