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The Causal Relationship between ICT and FDI

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Abstract

This paper investigates the simultaneous causal relationship between investments in information and communication technology (ICT) and flows of foreign direct investment (FDI), with reference to its implications on economic growth. For the empirical analysis we use data from 23 major countries with heterogeneous economic development for the period 1976–99. Our causality test results suggest that there is a causal relationship from ICT to FDI in developed countries, which means that a higher level of ICT investment leads to an increase inflow of FDI. ICT may contribute to economic growth indirectly by attracting more FDI. Contrarily, we could not find significant causality from ICT to FDI in developing countries. Instead, we have partial evidence of opposite causality relationship. The inflow of FDI causes further increases in ICT investment and production capacity.

Keywords: foreign direct investment, information and communication technology, stationarity, cointegration, causality, LSDV, 2SLS

JEL classification: C23, C33, C51, E22, F21

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1 Introduction

The growth of world foreign direct investment (FDI) in recent years has been remarkable. The US dollar value of world FDI inflows reached US$1.3 trillion in 2000 from just over US$200 billion in 1993. In 1980, FDI stock represented the equivalent of only 5 per cent of world GDP; this percentage had almost tripled to 14 per cent by the end of the 1990s. The share of developing countries in FDI inflows has been raised from 17.1 per cent in 1988–90 to 21.4 per cent in 1998–2000 (UNCTAD 2000). Over the last decade FDI flows have grown at least twice as fast as trade (Gorg and Greenaway 2004).

Empirical evidence that FDI has made a positive contribution to the economic growth of developing countries has accumulated fast. Some recent examples are Marwah and Klein (1998) for India; Li, Liu and Rebelo (1998), Sun (1998) and Liu (2002) for China; Ramirez (2000) for Mexico; Lim and McAleer (2002) for Singapore; Marwah and Tavakoli (2004) for Indonesia, Malaysia, the Philippines and Thailand. Borensztein, Gregorio and Lee (1998) and Makki and Somwaru (2004) are also among the cross-country studies which find positive impacts of FDI on economic growth in developing countries.

In general, most governments believe inward FDI can contribute to the growth of the host country's economy. Not surprisingly, since the 1980s, attracting FDI has been one of the most important policy goals of developing countries. These economies have not only liberalized restrictions on the inflows of FDI but also provided incentives to attract foreign investors. However, despite a higher return on investment, Asiedu (2002) finds that Africa is different and policies successful in other developing countries may not be as successful in attracting investors to the Sub-Saharan Africa.

So far many factors like infrastructure, human capital, low wages, natural resources, political stability are mentioned in the literature as determinants of FDI, but we should also consider changes in the global economy, especially the new information and communication technology (ICT) that has been reshaping the global system. There is a large literature on FDI, some of it dating 40 years or more. But the global economy has undergone massive change over the last 20 years, and what was relevant to attracting FDI in the 1970s may no longer be the case today (Addison and Heshmati 2004).

Addison and Rahman (2005) suggest that economies that successfully implement new ICT might be able to overcome barriers that have long held them back in their contribution in global trade (e.g. the limitation of a remote geography and an unfavourable climate). The rapid spread of the Internet has opened up the possibility of accessing commercial and political information that was previously unavailable. In particular, ICT has reduced many of the transaction costs of participating in sub-contracting through business-to-business (B2B) interaction, and it is facilitating the operations of low-cost suppliers of IT services based in developing countries (Matambalya and Wolf 2001).

Therefore ICT needs to be considered in explaining FDI flows. In a recent study, Addison and Heshmati (2004) examined the determinants of FDI, using a large sample of countries. Their findings suggest that ICT increases inflows of FDI to developing countries mainly because ICT lowers the transaction and production costs of foreign

investors, as well as improves their access to information on alternative investment opportunities in poorer economies.

The motivation of this study is to examine the existence and nature of any causal relationship between ICT and FDI inflows and its implications on economic growth. In the estimation of the causal relationship we control for degree of openness and GDP growth. This issue can be analysed using time-series and panel data analysis tools.[1] If non-stationary time-series variables are not cointegrated, then a high degree of correlation between two variables does not mean a causal relationship between the variables. Moreover, time-series methodology empowers us to recognize and avoid spurious results, which might happen when using a simple OLS method. We use Granger causality test, together with time-series analysis to investigate the causal relationship between ICT and FDI.

We also pool the country data to get the generalized results for developed countries and developing countries. For the panel causality analysis, we use least squares dummy variable (LSDV), and instrumental variables methods. To our knowledge, with the exception of Addison and Heshmati (2004), so far no attempts have been made to investigate the causal relationship between FDI and various determinants of FDI inflows based on long time-series and panel data analysis methodologies.

The main feature of this paper is its contribution to the analysis of causality among the primary key variables of interest, FDI and ICT, in a simultaneous framework conditional on GDP growth and openness. The hypothesis to be tested is whether the rich ICT infrastructure of the host country attracts more FDI. Sensitivity of the results with respect to estimation methods is also investigated. Empirical analysis is based on a sample of 23 developed and developing countries observed for the period 1976–99 based on ICT data availability.[2]

The organization of the paper is as follows. Following the introduction and a brief review of the literature in section 2, we explain the data and methodology for causality analysis in sections 3 and 4. Section 5 presents the estimation results, followed by the conclusion in the final section.

2 The impacts of FDI on economic growth

The recent trend of FDI has created opportunities and challenges for development and economic growth, especially for developing countries. The positive benefits of FDI to the receiving host country include capital, skill and technology transfer, market access, and export promotion. While some studies observe a positive impact of FDI on economic growth, others detect a negative relationship between these two variables (Aitken and Harrison 1999; Djankov and Hoekman 2000; Zukowska-Gagelmann 2002;

1 The impacts of ICT on FDI can be estimated using cross-sectional data. However, in a cross-sectional approach, it is not possible to control for country heterogeneity, nor to test for the direction of causation.

2 The countries studied include Austria, Australia, Brazil, Canada, Colombia, Denmark, Finland, France, Iceland, India, Indonesia, Ireland, Italy, Japan, Korea, Malaysia, Mexico, Norway, Singapore, Sweden, Turkey, the UK and US.

Konings 2001; Damijan *et al.* 2001; Castellani and Zanfei 2002a 2002b). The controversy has arisen partially due to data insufficiency in either cross-country or time-series investigations, using different samples of countries by different authors and various methodological problems.

According to Gorg and Greenaway (2004), there are also other explanations for a failure to find any evidence for positive aggregate spillovers. First, there may be lags to domestic firms' learning from MNEs which short-run analyses do not pick up. Second, MNEs may be able to guard their firm-specific advantages closely to prevent leakages to domestic firms and, therefore, no spillovers occur. Third, positive spillovers may only affect a sub-set of firms and aggregate studies, therefore, underestimate the true significance of such effects. Fourth, spillovers do not occur horizontally (i.e., intra-industry) but through vertical relationships which are missed in conventional spillover studies (Blalock and Gertler 2003).

More generally, while studies find a positive link between FDI and economic growth, FDI appears less positive in least developed countries, suggesting the existence of 'threshold level of development' (Blomstrom, Lipsey and Zejan 1994; Blomstrom and Kokko 2003; Nunnenkamp 2004). As OECD (2002: 69) concludes:

> Apparently, developing countries need to have reached a certain level of educational, technological and infrastructure development before being able to benefit from a foreign presence in their markets. An additional factor that may prevent a country from reaping the full benefits of FDI is imperfect and underdeveloped financial markets.

There is evidence that the absorptive capacity of domestic firms and geographic proximity to MNEs are important determinants of whether or not domestic firms benefit from FDI in the same sector. This suggests that spillovers may not affect all firms equally but that only certain firms, i.e., those with high levels of absorptive capacity and/or located close to MNEs, are able to benefit. Furthermore, the few studies that have looked at the potential for vertical (inter-industry) spillovers find evidence suggesting that the latter may be a more important channel for knowledge externalities than the former (Gorg and Greenaway 2004).

More recent empirical studies make use of panel data to correct for continuously evolving country-specific differences in technology, production and socioeconomic factors, thus eliminating many of the difficulties encountered in cross-country estimations (Islam 1995; Blomstrom, Lipsey and Zejan 1996; Bende-Nabende and Ford 1998; Nair-Reichert and Weinhold 2001; Bende-Nabende et al. 2002; Bende-Nabende et al. 2003; Choe 2003). Bengoa and Sanchez-Robles (2003) show that FDI is positively correlated with economic growth, but host countries require human capital, economic stability, and liberalized markets in order to benefit from long term FDI inflows. Using data on 80 countries for the period 1979–98, Durham (2004) fails to identify a positive relationship between FDI and economic growth, but suggests instead that the effects of FDI are contingent on the 'absorptive capability' of host countries. Li and Liu (2005) examine a panel of data for 84 countries over the period 1970–99. A significant endogenous relationship between FDI and economic growth was identified from the mid-1980s onwards.

Although some studies find negative impacts of FDI on growth, the more recent studies, which have employed more improved panel data and new econometric framework, have found more positive effects of FDI on the economic growth of the receiving host country.

2.1 Determinants of inflow of FDI

Traditional factors

Many factors have been considered in the literature as determinants of FDI. However, the selection of determinants is often ad hoc. The selection process is determined by the availability of data and the nature of the relations studied. The key determinants frequently appearing in the literature and their expected impact (in parentheses), include natural resources (+), market size (+), sociopolitical stability (+), tied business operating conditions (-), low wage costs (+), favourable exchange rate (+), trade barriers (-), export orientation (+), openness of developing host countries (+), democratization (+), risk (-), and in addition one should control for several other observable and unobservable time-specific and country-specific effects (Root and Ahmed, 1979; Dunning, 1980; Lunn, 1980; Dollar 1992; Chakrabarti 2001). A comprehensive study of determinants of FDI is beyond the scope of this paper. For a recent study where the flow of FDI is modelled in terms of traditional, new technology and political determinants as well as country characteristics, see Addison and Heshmati (2004). Here, the focus is on the causal relationship between FDI, ICT and economics growth.

New factors

ICT is considered as the main new determinant of FDI. The world is rapidly moving toward an information-based economy. Economies equipped with the essential ICT infrastructure have been moving towards an information-based economy.

> ICT offers a unique chance for countries to free themselves from the limitations of geography. Goods and services from these countries can be offered on the global market as efficiently as those from any other country through the use of ICT. The ever-developing ICT has fundamentally changed the nature of global relationships, competitive advantage and opportunities for economic and social development.[3]

Reduced transport costs, improved marketing information and increased efficiency of industrial production are among the main benefits of ICT. A large number of studies show that telecommunications infrastructure is not only essential for domestic economic growth, but also for attracting FDI and involvement in increasingly competitive world markets. Insufficient availability of ICT services is an inhibiting factor for economic growth in less developed countries (Matambalya and Wolf 2001; Addison and Heshmati 2004). Advanced telecommunication services facilitate international communications between parent companies and their overseas affiliates. The current trend of economic integration in the world economy is driven by cross-border investment by MNEs. Technological developments, particularly in ICT, have facilitated new ways of conducting business on a global scale (Pajarinen and Ylä-Anttila 2001).

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3 Report of the Regional Round Table on IT and Development, New Delhi, 21-22 June 2000.

In looking at the relationship between ICT and FDI, one should find a linkage to economic theory by looking at the (i) skills and productivity, that is the human capital aspects of ICT, (ii) transfer of technology, (iii) the transaction cost effects, and (iv) the infrastructure aspect of ICT or its impacts on the inflow FDI emphasized in this study. As mentioned earlier, the ICT literature considers ICT as reducing the international transactions costs (Clemons and Row 1991; Gurbaxani and Whang 1991; Hitt 1999, Jorgenson 2001). Human capital is relevant in terms of the ability to assimilate both ICT and technology transfer.

The economic role of ICT in determining FDI inflows as shown in Addison and Heshmati (2004) can also be explained by a conceptual framework of the Ricardian two-country model of trade (Dornbusch et al., 1977; Dornbusch and Park, 1987) to illustrate the effects of ICT on the host country's economy. The Ricardian model is constructed so that the only difference between countries is in their production technologies and highlights one of the main reasons why countries trade (host country identified by FDI here); namely, differences in technology. It deals with the effects of technology on relative wages and the decision to (re)locate production to developing countries.

3 The data

The data used in this study consist of a sample of 23 countries observed for the period 1976–99. The ICT variable is from the ITU's (2002) World Telecommunication Indicators Database. Annual investment in telecommunications is a proxy for ICT.[4] Following the tradition in the literature, we define FDI as net flows of foreign direct investment expressed as a percentage of GDP (World Bank 2002). The data, a balanced panel, are chosen based on the availability of ICT variable. The dependent variable is FDI and the independent variables are the key determinants of FDI, openness, GDP growth, and ICT investment. Here the focus is on examination of the causal relationship between FDI and ICT conditional on other key variables rather than specification and estimation of FDI and ICT models. In defining the dependent variable, FDI, we do not distinguish between local market and non-local market seeking FDI (Asiedu 2002).

Openness of the economy is defined as the trade (import plus export) share of GDP. FDI is expected to be positively associated with the openness of the host country; that is economies in which trade is important also have relatively higher FDI. We use GDP growth measured by the annual growth rate. There is a positive relationship between GDP growth and FDI, explaining the fact that horizontal FDI (FDI looking for the domestic market) is attracted to economies in which real income, and therefore domestic purchasing power, is growing. A positive and high growth rate indicates high and growing productivity of labour and returns on investment.

4 The ICT investment is limited to investment in ICT in the host country. It does not include investment in ICT through FDI since FDI cannot be decomposed into knowledge-based and non-knowledge-based investment components. However, it is possible to use the measurement error approach to account for possible errors in the explanatory variables.

4 Empirical model

The causal relationship between the likely interdependent variables of FDI and ICT is studied using time-series, fixed effects and instrumental variable panel data approaches. A comparison of the results based on alternative methods sheds lights on the sensitivity of causality relationship due to the choice of data and estimation methods.

4.1 Time-series Granger causality analysis

Since Granger (1969) and Sims (1972), the most widely used operational definition of causality is the Granger definition of causality. It is defined as follows: x is a Granger cause of y (denoted as $x \rightarrow y$), if present y can be predicted with better accuracy by using past values of x rather than by not doing so. Later on, Granger (1980) pointed out that the Granger causality test might produce spurious results if variables are cointegrated with a first order of integration. In this case, an error-correction model (ECM) should be used to establish true causality relationship. The residual of the cointegrating vector becomes the error correction term (ECT) that is used in the error correction model to eliminate the spurious results.

First, we need to apply the Augmented Dickey Fuller (ADF) test to determine the variables' stationarity and order of integration (Dickey and Fuller 1979, 1981). If variables have a different order of integration, then obviously they are not cointegrated and no further investigation of cointegration is needed. Otherwise, if they are integrated, we use the Johansen (1988) model, which was extended by Johansen and Juselius (1990) for conducting the cointegration test.

Cointegration shows the long-run relationship between two variables. A lack of such relationship follows tests for a short-run relationship based on the causality test. When variables are not cointegrated, after acquiring the stationary series (obtained from differencing), we use a vector autoregression (VAR) model for each country. Here we have a number of key determinants of FDI, such as: ICT investment, openness and GDP growth. There is a positive association between openness and FDI. GDP growth also has a positive impact on FDI. We have chosen these key variables, which are the most common variables considered in previous studies.

$$FDI_t = \alpha_1 + \sum_{i=1}^{M} a_i FDI_{t-i} + \sum_{j=1}^{N} b_j ICT_{t-j} + \sum_{k=1}^{K} c_k GDP_{t-k} + \sum_{l=1}^{L} d_l OPEN_{t-l} + u_t \quad (1)$$

$$ICT_t = \alpha_2 + \sum_{i=1}^{M} e_i ICT_{t-i} + \sum_{j=1}^{N} f_j FDI_{t-j} + \sum_{k=1}^{K} g_k GDP_{t-k} + \sum_{l=1}^{L} h_l OPEN_{t-l} + \omega_t \quad (2)$$

where t indicates time period. We selected the lag structure of the model based on Akaike Information Criteria (AIC), at the 5 per cent level reported by E-views. ICT Granger-causes FDI if $H_0 : b_1 = b_2 = ... = b_M = 0$ is rejected. The role applies to the remaining variables in equation (1) namely GDP growth and openness, as well as to all other three equations in the system.

4.2 Panel data causality analysis

The introduction of a panel data dimension allows using both cross-sectional and time-series information to test the causality relationships between y and x. In particular, it provides the researcher with a large number of observations, increasing the degree of freedom and reducing the multi-collinearity among explanatory variables. So, it noticeably improves the efficiency of Granger causality tests. Pooling cross-sectional units does have certain advantages; the assumption of time stationarity can be relaxed. The disadvantage is imposing the strong assumption of homogenous behaviour or responsiveness to changes in the exogenous variables across countries. We consider the following VAR model:

$$FDI_{it} = \alpha_1 + \sum_{m=1}^{M} a_m FDI_{i,t-m} + \sum_{n=1}^{N} b_n ICT_{i,t-n} + \sum_{k=1}^{K} c_k GDP_{i,t-k} + \sum_{l=1}^{L} d_l OPEN_{i,t-l} + u_{it} \quad (3)$$

$$ICT_{it} = \alpha_2 + \sum_{m=1}^{M} e_m ICT_{i,t-m} + \sum_{n=1}^{N} f_n FDI_{i,t-j} + \sum_{k=1}^{K} g_k GDP_{i,t-k} + \sum_{l=1}^{L} h_l OPEN_{i,t-l} + \omega_{it} \quad (4)$$

where *FDI* is the FDI share of GDP of country i (i = 1,…, N) in period t (t = 1,…, T), u_{it} is the error term. The error term follows a two-way error component structure (Baltagi 2001) and can be broken down into an unobservable country-specific (μ_i), a time-specific (λ_t), and a random error term (v_{it}) components as:

$$u_{it} = \mu_i + \lambda_t + v_{it}\,. \quad (5)$$

The error term v_{it} represents measurement errors in the dependent variable and omitted explanatory variables and random shocks. The error term is assumed to be independently and identically distributed with zero mean and constant variance, σ^2. Similar decomposition applies to ω_{it}. The country and time-specific effects, μ_i and λ_t, are factors representing country heterogeneity and neutral shift in the FDI flows over time respectively and assumed to be independent of each other and of the regressors.

In the literature, the unobservable country effects μ_i are represented by country dummies and the time effects λ_t are often replaced with a time trend reducing the two-way error component model to a one-way error component model. In the panel literature the estimation of the model (3) has been developed in two directions, the fixed effect (FE) model where μ_i is assumed to be fixed and correlated with explanatory variables, and the random effects (RE) model where μ_i is assumed to be random and not correlated with the explanatory variables. In this study we use the FE model since we have a relatively small sample of countries not chosen randomly. Furthermore, the country heterogeneity effects are important with regard to the flow of FDI. Despite the relatively high coverage in terms of world's GDP and total population, all inferences here are made only on the included sample of countries.

4.3 A method of instrumental variables

To date, most causality tests have used time-series data. However, it is difficult to control for measurement errors and omitted variable problems. To overcome these problems, we apply an instrumental variable two-stage least squares (2SLS) technique

to conduct the causality test. The idea is to account for the endogeneity of regressors using instrumental variable methods. This method can be used when standard regression estimates of the relation of interest are biased because of reverse causality, selection bias, measurement error, or the presence of unmeasured confounding effects.

The central idea is to use a third, instrumental variable to extract variation in the variable for interest that is unrelated to the above problems, and to use this variation to estimate its causal effect on an outcome measure. The 2SLS estimator increases computational efficiency without detracting significantly from its effectiveness.

A typical example of traditional panel data causality testing is Holtz-Eakin, Newey and Rosen (1988). The Holtz-Eakin model is:

$$y_{it} = \alpha_1 + \sum_{j=1}^{m} \alpha_j y_{i,t-j} + \sum_{j=1}^{m} \delta_j x_{i,t-j} + \mu_i + v_{it} \tag{6}$$

where i =1…N. In order to eliminate the fixed effects, μ_i, the authors difference the data leading to the model:

$$y_{it} - y_{i,t-1} = \sum_{j=1}^{m} \alpha_j (y_{i,t-j} - y_{i,t-j-1}) + \sum_{j=1}^{m} \delta_j (x_{i,t-j} - x_{i,t-j-1}) + (v_{it} - v_{i,t-1}) \tag{7}$$

This specification introduces a problem of simultaneity because the error term is correlated with the regressor $y_{i,t-j} - y_{i,t-j-1}$. Therefore, a 2SLS instrumental variables procedure with a time-varying set of instruments is used to estimate the model. Anderson and Hsiao (1982), suggest IV on the differenced model using y lagged twice, $y_{(-2)}$ and differenced x's as instruments (Δx). The authors then equate the question of whether or not x causes y with a test of the joint hypothesis: $\delta_1 = \delta_2 = ... = \delta_m = 0$. The three approaches each have their benefits and limitations. Unlike in the panel data approach, the country time-series model ignores heterogeneity in responses by the sample countries. While accounting for country effects complicates the estimation procedure, the IV approach increases the effectiveness in the estimation. For estimation purposes, we have used the 2SLS estimation procedure available in E-views.

5 Empirical results and discussion

5.1 The test results

Table 1 presents the results of the unit root tests using the Augmented-Dickey-Fuller test. For each of the four series examined, the test statistics suggest that the levels of the series are not stationary. They are integrated of order 1 or 2, which means that the series becomes stationary after taking the first or the second differences. Now that we know the level of integration of the series we proceed to test for the cointegration. This is necessary to test for the presence of causality relationship between the variables in the next step. The results of the Johansen trace and maximal eigenvalue cointegration tests are provided in Table 2. Results suggest that there is not enough evidence of cointegration between FDI and ICT in most of the countries in our sample.

Even for a few countries like Denmark, Japan, Malaysia, Singapore and Norway the significance level is weak. Since ICT and FDI are not cointegrated, an absence of cointegration suggest that the use of OLS might lead to spurious results. Alternative estimation methods like fixed/random effects models and instrumental variable methods are more appropriate methods to perform Granger causality test. The causality test results, together with unit root tests, are shown in Table 1. Among 16 developed countries and newly industrialized economies (NIE), six countries show the significant Granger causality from ICT to FDI, while among seven developing countries three countries have the same causality relationship, i.e. from ICT to FDI.

For the causality from FDI to ICT, seven of 16 developed/NIE countries had statistically significant results while two out of seven developing countries were significant. To obtain the generalized finding on ICT and FDI relationship in developed countries and developing countries, we perform the panel data analysis and results are shown in Table 3. Again, H_1 denotes the null hypothesis that ICT does not Granger cause FDI, and H_2 denotes the null hypothesis that FDI does not Granger cause ICT. The results are discussed in the next section.

5.2 Discussion of the results

Our causality test results significantly suggest that there is a causal relationship from ICT to FDI in developed countries. This suggests that developed countries' ICT infrastructure is an important factor in attracting foreign investors to undertake investment in those countries. However, in developing countries, we could not find any significant causality from ICT to FDI. Instead, we found partial evidence of the opposite causality from FDI to ICT, which means inflows of FDI generate new ICT investment to facilitate improved production potential in developing countries.

The causality from ICT to FDI in developed countries implies that ICT may contribute to economic growth indirectly by attracting more FDI. Increases in information and knowledge may result in efficient collaboration and coordination. Up-to-date and accurate information on consumers, suppliers and competitors is essential for successful businesses. Telecommunications and information technology increases information availability and accuracy and provides better conditions for businesses. ICT is considered as a production factor with great impact on skill and productivity of labour. Therefore, ICT can attract more FDI to developed countries.

Traditionally, FDI to developing countries in comparison to FDI to developed countries requires less ICT investment, lower skilled labour input and less advanced production techniques. However, in many developing countries, the level of ICT infrastructure is not high enough to attract FDI, yet. Without external support, a developing country with a lower level of ICT infrastructure has less capability internally to finance high ICT capacity. Therefore, these countries may need to bring in more FDI to promote their ICT industry. To mention a few examples of FDI investment and the importance of ICT infrastructure, for instance, MNEs like Intel, IBM and Motorola have moved to Asia and other developing countries and started e-commerce services there. Dell Computer, for example, established a manufacturing plant in Malaysia in 1996. It also opened the first foreign-owned PC manufacturing plant in mainland China in August 1999. In Brazil, PC sales are growing at a rate of 30 per cent per year, which has attracted

investments from foreign ICT companies like America Online, Oracle, Commerce One, Dell and Compaq (Nain and Anuar 1996).

It seems that the less developed economies should accelerate their deployment of ICT to avoid falling further behind in economic competitiveness. Ireland takes advantage of the ability of ICT to make up for its disadvantage with regard to geographical location. Similarly to Europe and other developed countries, ICT in Ireland has been the engine of growth. Remarkably, Ireland started to attract FDI in the technology sector through attractive human capital and tax structure incentives. Recent cross-country empirical research has also tried to estimate the importance of ICT to decisions on FDI location. A recent study by the World Bank (2001) found a positive relationship between tele-density (telephone lines per capita) and inflows of FDI. A similar study came to the conclusion that when countries have one more phone per 100 people than the average number of telephones expected at their given income level, they receive 0.3 cents per US$100 of GDP more foreign investment than countries with an average number of telephones (Reynolds et al. 2001). However, in several countries the fixed phone connectivity is lower than mobile phone connectivity rate and not a good representation of development infrastructure. A composite index incorporating several elements including phone and intra- and internet connectivity is more appropriate measure of ICT infrastructure.

Newly industrialized economies and some of the developing countries like Singapore, Malaysia, South Africa, and India have already realized that a strong ICT sector attracts FDI. These countries have been persistently improving their ICT infrastructure and have become regional leaders in attracting FDI (e.g. Malaysia's US$20 billion Multimedia Super-corridor; India's liberalization of trade regime for the high-tech sector; South Africa's Info.Com 2025, a programme to promote ICT development in addition to attracting foreign investment).[5] Singapore's economic development strategy is focused on the development of its ICT sector. Thanks to large investments in telecommunications infrastructure together with liberal trade policies to attract FDI since the early 1970s, the island quickly became a regional hub for the high-tech manufacturing industry in Asia. Over 4,000 multinationals have operations in Singapore, which has resulted in technology transfer, a well-functioning financial market as well as a booming market for small and medium enterprises that provide outsourcing services and a successful domestic electronics production sector.

As mentioned earlier, ICT attracts FDI since the availability of advanced infrastructure is an essential concern in decisions on investment location for foreign investors. Geography and distance are less important factors in production/location decisions as communications and transaction costs continue to fall. Mody's (1997) survey of international firms in Hong Kong, Singapore and Taiwan found that the presence of advanced infrastructure was the most important consideration of multinational companies in the placement of regional headquarters, services and sourcing operations.

5 See www.ecomm-debate.co.z/docs/discuss07.html and Department of Communications, Republic of South Africa, 1999, for more information.

6 Conclusions

Previous research suggests that the positive impacts of FDI on the economic development of the host countries include inflow of capital, skill and technology transfer, market access, new investment opportunities and export promotion. Therefore, governments, especially in developing countries, have recently not only liberalized restrictions on FDI but also provided incentives to attract more FDI. A variety of factors are cited in the literature including infrastructure, human capital, low wages and political stability, as determinants of FDI. However, we must also take account of deeper and broader changes in the global economy, especially the spread of the new economy, and the new ICT revolution as several recent studies have shown that ICT has a positive effect on FDI inflows.

In this study, we examined this issue with the time-series and panel data analysis methods including least square dummy variables and instrumental variable estimation methods. Our sequence of tests indicates that there is not enough evidence of any long-run cointegration relationship between the variables.

Results from the Granger causality test indicate that there is a significant short-run causal relationship between the variables among the countries. However, the results differ according to the country's level of development. In developed countries, existing ICT infrastructure attracts FDI; a higher level of ICT investment leads to a higher level of FDI inflows. This suggests that ICT contributes to productivity and economic growth indirectly by attracting more FDI. But in developing countries the direction of causality goes instead from FDI to ICT. In developed countries an ICT capacity exists which causes inflow of FDI, while in developing countries ICT capacity must be built up in order to attract FDI. The inflow of FDI causes further increases in ICT investment and production capacity building.

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Table 1
Results of ADF unit root and Granger-causality tests

Developed/ NIE country	Series	Degree of integration	Hypothesis	F statistics	Result	Country	Series	Degree of integration	Hypothesis	F statistics	Result
Australia	FDI	I(1)	H_1	0.653	No	Italy	FDI	I(0)	H_1	0.377	No
	GDP	I(2)					GDP	I(1)			
	ICT	I(2)	H_2	2.701	FDI→ICT**		ICT	I(2)	H_2	2.897	FDI→ICT**
	Open	I(2)					Open	I(2)			
Austria	FDI	I(2)	H_1	6.437	ICT→ FDI**	Japan	FDI	I(2)	H_1	0.096	No
	GDP	I(1)					GDP	I(2)			
	ICT	I(1)	H_2	2.271	No		ICT	I(2)	H_2	4.939	FDI→ICT**
	Open	I(2)					Open	I(1)			
Canada	FDI	I(1)	H_1	0.016	No	Korea	FDI	I(2)	H_1	0.707	No
	GDP	I(2)					GDP	I(0)			
	ICT	I(1)	H_2	0.136	No		ICT	I(1)	H_2	0.469	No
	Open	I(2)					Open	I(2)			
Denmark	FDI	I(2)	H_1	0.117	No	Norway	FDI	I(1)	H_1	1.773	No
	GDP	I(0)					GDP	I(2)			
	ICT	I(2)	H_2	0.263	No		ICT	I(1)	H_2	1.543	No
	Open	I(2)					Open	I(1)			
Finland	FDI	I(1)	H_1	6.764	ICT→FDI**	Singapore	FDI	I(1)	H_1	3.940	ICT→FDI**
	GDP	I(2)					GDP	I(2)			
	ICT	I(2)	H_2	4.393	FDI→ICT**		ICT	I(1)	H_2	11.239	FDI→ICT**
	Open	I(2)					Open	I(2)			
France	FDI	I(2)	H_1	0.329	No	Sweden	FDI	I(2)	H_1	0.761	No
	GDP	I(2)					GDP	I(2)			
	ICT	I(1)	H_2	0.089	No		ICT	I(2)	H_2	2.981	FDI→ICT**
	Open	I(2)					Open	I(2)			
Iceland	FDI	I(1)	H_1	4.148	ICT→FDI**	UK	FDI	I(1)	H_1	3.065	ICT→FDI**
	GDP	I(2)					GDP	I(2)			
	ICT	I(2)	H_2	0.701	No		ICT	I(2)	H_2	0.7439	No
	Open	I(2)					Open	I(2)			
Ireland	FDI	I(2)	H_1	4.366	No	US	FDI	I(2)	H_1	7.255	ICT→FDI**
	GDP	I(2)					GDP	I(1)			
	ICT	I(2)	H_2	18.680	FDI→ICT**		ICT	I(2)	H_2	2.372	No
	Open	I(1)					Open	I(2)			

Table 1 continues

Table 1 (con't)
Results of ADF unit root and Granger-causality tests

Developed/ NIE country	Series	Degree of integration	Hypothesis	F statistics	Result	Country	Series	Degree of integration	Hypothesis	F statistics	Result
Developing countries											
						Brazil	FDI	I(2)	H_1	7.189	ICT→ FDI**
							GDP	I(1)			
							ICT	I(2)	H_2	4.880	FDI→ICT**
							Open	I(2)			
India	FDI	I(0)	H_1	0.101	No	Colombia	FDI	I(1)	H_1	2.002	No
	GDP	I(1)					GDP	I(1)			
	ICT	I(1)	H_2	2.244	No		ICT	I(1)	H_2	7.389	FDI→ICT**
	Open	I(2)					Open	I(1)			
Indonesia	FDI	I(2)	H_1	12.767	ICT→FDI**	Mexico	FDI	I(1)	H_1	2.442	No
	GDP	I(1)					GDP	I(1)			
	ICT	I(2)	H_2	4.422	No		ICT	I(2)	H_2	0.465	No
	Open	I(2)					Open	I(1)			
Malaysia	FDI	I(2)	H_1	4.294	ICT→FDI**	Turkey	FDI	I(1)	H_1	0.986	No
	GDP	I(1)					GDP	I(2)			
	ICT	I(2)	H_2	0.093	No		ICT	I(1)	H_2	2.356	No
	Open	I(1)					Open	I(2)			

Notes: **, * 5% and 10% significance levels, respectively. H_1 denotes the null hypothesis that ICT does not Granger cause FDI, and H_2 denotes the null hypothesis that FDI does not Granger cause ICT. Estimated results from equations (1) and (2).

Table 2
Results of Johansen cointegration test

Country	No. of cointegrating equation(s)	Eigenvalue	Trace statistic	10% CV	5% CV	Max-Eigen Statistics	10% CV	5% CV
Australia	None	0.339875	9.342091	15.41	20.04	9.137187	14.07	18.63
	At most 1	0.009271	0.204904	3.76	6.65	0.204904	3.76	6.65
Brazil	None	0.339875	9.342091	15.41	20.04	9.137187	14.07	18.63
	At most 1	0.009271	0.204904	3.76	6.65	0.204904	3.76	6.65
Canada	None	0.355510	11.65731	15.41	20.04	9.664523	14.07	18.63
	At most 1	0.086600	1.992785	3.76	6.65	1.992785	3.76	6.65
Colombia	None	0.350976	10.64254	15.41	20.04	9.077997	14.07	18.63
	At most 1	0.071794	1.564540	3.76	6.65	1.564540	3.76	6.65
Denmark	None *	0.447209	17.62515	15.41	20.04	11.85552	14.07	18.63
	At most 1 *	0.250600	5.769636	3.76	6.65	5.769636	3.76	6.65
France	None	0.473604	14.93944	15.41	20.04	12.83403	14.07	18.63
	At most 1	0.099919	2.105402	3.76	6.65	2.105402	3.76	6.65
Indonesia	None	0.400234	13.95718	15.41	20.04	10.73553	14.07	18.63
	At most 1	0.142223	3.221645	3.76	6.65	3.221645	3.76	6.65
Ireland	None	0.459974	15.31655	15.41	20.04	12.93889	14.07	18.63
	At most 1	0.107048	2.377664	3.76	6.65	2.377664	3.76	6.65
Japan	None **	0.884211	45.73395	15.41	20.04	40.96368	14.07	18.63
	At most 1 *	0.222029	4.770266	3.76	6.65	4.770266	3.76	6.65
Kenya	None	0.330483	14.35184	15.41	20.04	8.826360	14.07	18.63
	At most 1	0.222101	5.525475	3.76	6.65	5.525475	3.76	6.65
Korea	None	0.309321	8.474567	15.41	20.04	8.141772	14.07	18.63
	At most 1	0.015013	0.332795	3.76	6.65	0.332795	3.76	6.65
Malaysia	None **	0.736293	30.66006	15.41	20.04	26.65831	14.07	18.63
	At most 1 *	0.181341	4.001750	3.76	6.65	4.001750	3.76	6.65
Norway	None *	0.497217	15.50969	15.41	20.04	15.12713	14.07	18.63
	At most 1	0.017239	0.382555	3.76	6.65	0.382555	3.76	6.65
Singapore	None *	0.491645	19.23287	15.41	20.04	13.53150	14.07	18.63
	At most 1 *	0.248037	5.701369	3.76	6.65	5.701369	3.76	6.65
Sweden	None	0.279644	10.41375	15.41	20.04	6.888204	14.07	18.63
	At most 1	0.154547	3.525543	3.76	6.65	3.525543	3.76	6.65
Turkey	None	0.383233	12.66360	15.41	20.04	10.63181	14.07	18.63
	At most 1	0.088218	2.031790	3.76	6.65	2.031790	3.76	6.65
US	None	0.356793	12.07578	15.41	20.04	9.267078	14.07	18.63
	At most 1	0.125189	2.808705	3.76	6.65	2.808705	3.76	6.65

Notes to Table 2

: **, * 5% and 10% significance levels respectively. Critical values (CV). For the variables be cointegrated, the order of integration of the left-hand-side variable (FDI) should be equal to or greater than the highest order of integration of the right-hand-side variables (ICT, OPEN, and GDP). This applies to 17 countries in our sample presented in Table 2. Otherwise, even without cointegration tests, they are obviously not cointegrated.

Table 3
Results of panel causality tests from LSDV and instrumental variable estimation

Group	Hypothesis	F- statistics (LSDV)	Result	F- statistics (2SLS)	Result
Developed countries					
	H_1	2.630453	ICT→ FDI**	5.414236	ICT→ FDI**
	H_2	0.142199	No	0.366966	No
Developing countries					
	H_1	2.407414	No	0.535967	No
	H_2	3.193571	FDI→ICT**	0.490896	No

Notes: **, 5% significance level, H_1 denotes the alternative hypothesis that ICT does not Granger cause FDI, and H_2 denotes the alternative hypothesis that FDI does not Granger cause ICT.