THE CONTRIBUTION OF INFORMATION COMMUNICATION TECHNOLOGY (ICT) TO TOTAL FACTOR PRODUCTIVITY (TFP) AND ECONOMIC GROWTH: EVIDENCE FROM ASIA-PACIFIC AND EU COUNTRIES

FARZANEH KHALILI

FACULTY OF ECONOMICS AND ADMINISTRATION
UNIVERSITY OF MALAYA
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ABSTRACT

The impact of information and communications technology (ICT) on the economy has become a fundamental part of industrial economics. This is due to the key role played by ICT in the industrial sector and economy as a whole. When ICT is considered as just an input under the growth accounting approach, it fails to capture the impact of ICT as a Solow residual. This thesis, through the use of two channels, firstly, the growth accounting approach, and, secondly, the endogenous growth model, fully captures the spillover effects of ICT on economic growth. To overcome the methodological limitation found in previous studies, this thesis has adopted a relatively new panel data techniques and added new controlling variables that are expected to have potential as additional growth drivers. We have used two different panel data approaches to estimate the ICT effects. Firstly, Pooled Mean Group (PMG), Mean Group (MG) and Dynamic Fixed Effect (DFE) estimators are applied to identify the direction of causality under vector error correction representation. Secondly, to deal with the endogeneity problem, Generalised Methods of Moments (GMM) estimators are employed to estimate the long run association among labour employment, ICT, non-ICT, TFP contribution and output growth through cross-industry and cross-country analyses. The sample period covers from 1990 to 2011 of which is further divided into two sub-periods, 1990 to 2000 and 2001 to 2011 respectively. This study obtains empirical results from a group of countries at the aggregate and industrial levels. The industrial level findings reveal that there is a unidirectional short run causal relationship running from economic growth to ICT contribution for Japan, Finland and Denmark but that relationship is bidirectional in the long run. Furthermore, the dynamic panel results for Sweden and Australia show bidirectional causality among ICT, TFP contribution and economic growth both in the long run and short run. ICT has no significant effect on TFP growth in Japan and Finland, whereas a negative relationship between ICT and TFP may reveal a productivity paradox in Denmark, Australia and Sweden. The outcomes in five countries show that returns were smaller in ICT-using than ICT-producing industries and that no significant complementary impacts exist between ICT and non-ICT capital. At the country level, GMM estimates indicate that the long run growth impact of ICT in the Asia-Pacific and EU countries is not uniform between two sub-periods. The growth impact of ICT was stronger in Asia-Pacific countries during the first sub-period as opposed to the EU. In contrast, EU led Asia-Pacific countries in the second sub-period. For short run causality, it is found that there is unidirectional flow from GDP growth to ICT contribution for both regions. Moreover, the EU countries benefit from the spillover effects of ICT whereas there is no causal relationship between ICT and TFP growth in Asia-Pacific countries. Aggregating at the country level, the result reveals that ICT has a higher positive spillover effect on value added growth through TFP in ICT developed countries as compared to ICT less developed countries. The thesis concludes with a few policy implications. First, the effect of ICT on growth is not static but a long and dynamic process. Second, there is robust potential to exploit growth profits in service industries that make intensive use of ICT. Finally, advocating ICT diffusion within the economy is much more growth enhancing than just concentrating on the ICT-producing sectors.

ABSTRAK

Impak teknologi maklumat dan komunikasi (ICT) terhadap ekonomi telah menjadi sesuatu yang asas dalam bidang ekonomi industri. Ini disebabkan peranan penting yang dimainkan oleh ICT dalam sektor industri dan ekonomi secara keseluruhannya. Apabila ICT dianggap sebagai salah satu input di bawah pendekatan pertumbuhan perakaunan, ia tidak mengukur impak ICT sebagai residue Solow. Tesis ini, melalui dua saluran, pertama, pendekatan pertumbuhan perakaunan, dan kedua, model pembangunan endogenus, untuk mengukur kesan "spillover" ICT idalam pertumbuhan ekonomi. Untuk mengatasi kekangan metodologi yang dijumpai dalam kajian terdahulu, tesis ini telah menggunakan pendekatan data panel yang lebih baru serta menambahkan variabel kawalan yang berpotensi menjadi pemangkin pembangunan. Kami telah menggunakan dua pendekatan data panel untuk mengukur kesan ICT. Pertama, Penganggar-penganggar seperti Kumpulan Min Terkumpul (PMG), Kumpulan Min (MG) serta Kesan Tetap Dinamik (DFE) telah digunakan untuk mengenalpasti arah sebab penyebab di bawah representasi "Vector Error Correction". Kedua, untuk mengatasi masalah endogeneiti, penganggar Kaedah Momen Umum (GMM) akan digunakan untuk menganggar hubungan jangka panjang di antara buruh, pekerjaan, ICT, bukan ICT, sumbangan TFP dan pertumbuhan output melalui analisis di antara industri dan antara negara. Tempoh sampel dari 1990 ke 2011 telah digunakan di mana ianya dibahagikan kepada dua bahagian, 1990-2000 dan 2001-2011. Kajian ini mendapat kuputusan empirikal dari satu kumpulan negara pada peringkat agregat dan indutri. Keputusan dari peringkat industri mendapati bahawa terdapat kesan penyebab jangka pendek sehala dari pembangunan ekonomi ke sumbangan ICT untuk Jepun, Finland dan Demark manakala kesan dua hala didapati dalam jangka panjang. Tambahan pula, keputusan dinamik dari panel untuk Sweden dan Australia mendapati kesan penyebab dua hala di antara ICT, sumbangan TFP dan pembangunan ekonomi sama ada untuk jangka masa

panjang dan pendek. ICT tidak berkesan terhadap pertumbuhan TFP di Jepun dan Finland manakala hubungan negatif di antara ICT dan TFP mungkin menunjukkan kewujudan paradoks produktiviti di Demark, Australia dan Sweden. Keputusan dari lima negara menunjukkan pulangan adalah kurang untuk industri penggunaan ICT berbanding kepada industri pengeluaran ICT. Selain itu, tiada kesan pelengkap di antara modal ICT dan bukan ICT. Di peringkat negara, penganggar GMM menunjukkan kesan pertumbuhan jangka panjang ICT di negara-negara di Asia-Pasifik dan EU adalah tidak sekata di antara dua tempoh. Kesan pertumbuhan ICT adalah lebih kuat di Asia-Pasifik berbanding dengan negara di EU dalam sub-tempoh pertama. Sebaliknya, kesan pertumbuhan di negara EU adalah baik daripada negara di Asia-Pasifik di dalam sub-tempoh kedua. Untuk kesan penyebab jangka pendek, didapati bahawa terdapat aliran satu hala dari pertumbuhan GDP ke sumbangan ICT untuk kedua-dua rantau. Selain daripada itu, negara-negara di EU dapat menikmati kesan "spillover" dari ICT manakala tidak ada kesan penyebab di antara ICT dan pertumbuhan TFP di negara Asia-Pasifik. Melihat secara agregat pada peringkat negara, keputusan menunjukkan ICT mempunyai kesan "spillover" pada pertumbuhan nilai tambahan melalui TFP di negara maju ICT berbanding negara yang kurang maju di bidang ICT. Hasil kajian tesis ini mempunyai implikasi dasar yang penting. Pertama, kesan ICT kepada pertumbuhan bukan statik tetapi satu fenomena yang bersifat dinamik serta mengambil masa yang panjang. Kedua, terdapat potensi yang baik untuk memanfaatkan pertumbuhan dalam industri perkhidmatan yang menggunakan ICT secara intesif. Akhir sekali, menggalakkan penyebaran ICT di seluruh ekonomi adalah lebih penting untuk menggiatkan pertumbuhan ekonomi daripada hanya memberi fokus kepada sektor yang menghasilkan ICT.

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My best wishes to all of them

Farzaneh Khalili

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LIST OF SYMBOLS AND ABBREVIATIONS

ICT	Information Communication Technology
IT	Information Technology
GPT	General Propose Technology
TFP	Total Factor Productivity
Non_ICT	Non Information Communication Technology
EG	Economic Growth
ITU	International Telecommunication Union
CT	Communications Technology
DSL	Digital Subscriber Line
A	Elasticities
A	Solow Residual
ATMs	Automated Teller Machines
GDP	Gross Domestic Product
WBI	World Bank Indicators
IDI	ICT Development Index
OECD	Organisation for Economic Co-operation and Development Countries
EDI	Electronic Data Interchange
APL	Labour Productivity
BLS	Bureau of Labour Statistics
R&D	Research and Development
LSDV	Least Square Dummy Variables
PMG	Pooled Mean Group
MG	Mean Group
DFE	Dynamic Fixed Effect
GMM	Generalised Moment of Method
OPEC	Organization of the Petroleum Exporting Countries
PDOLS	Panel Dynamic Ordinary Least Squares
OLS	Ordinary Least Squares

3SLS	Three-stage Least Squares
Gi	Growth Gap
PRO_F	Productivity in Frontier Group Countries
PRO_I	Productivity Flowers Group Countries
PRO_i	Labour Productivity
CEE	Central and Eastern European
ECT	Error Correction Term
ECM	Error-Correction Model
VECM	Vector Error Correction Model
U_{it}	Error Term
Y_{it}	Value Added Growth
$\beta_1, \beta_2, \beta_3$	Elasticities of the Production Resources
ICT_prod	ICT-producing Industries
ICT_use	ICT Using Industries
K_{ICT}	Information Communication Technology Capital
$K_{non-ICT}$	Non Information Communication Technology Capital
L_{it}	Labour Capital
Ictim	ICT Goods Imports
Ptn	Patent Applications, Non-residents
Ptr	Patent Applications, Residents
Terit	School Enrolment, Tertiary
Ht	High-Technology Exports
Upl	Unemployment
Exp	Exports of Goods and Services
Imp	Imports of Goods and Services
VAR	Vector Auto-Regression
DF	Dickey-Fuller
ADF	Augmented Dickey-Fuller
CADF	Cross-sectional Augmented Dickey-Fuller
PP	Phillips-Perron

AIC	Akaike Information Criterion
LM	Lagrange Multiplier
η_i	Country
δ_i	Industry
e_{it}	Estimated Residuals
μi	Fixed Effects for Each Industry or Country
λij	Coefficients of the Lagged Dependent Variables
δij	Coefficients of Current and Lagged Independent Variables
T	Time Observations
N	Cross-sectional Observations
ARDL	Autoregressive Distributed Lag Model
ASEAN	Association of Southeast Asian Nations
IVs	Instruments
NICTA	Australia's Information and Communications Technology Research Centre of Excellence
IPS	Im, Pesaran & Shin (1997) Test
KT	Korea Telecom
C&W	Cable and Wireless Services
CIs	Cluster Initiatives

CHAPTER 1: BACKGROUND OF STUDY AND STATEMENT OF RESEARCH

1.1 Introduction

In recent years, one of the most essential concerns of economists is whether the accumulation of Information Communication Technology (ICT) capital positively contributes to the growth in income and productivity in various countries. This uncertainty has prompted vigorous debate among economists. One camp has argued that the improvement of ICT is among a series of positive provisional shocks, thus, having no effect on expansion, while another camp claimed that it leads to increasing growth prospects as it has produced a fundamental change in the economy.

ICT is a kind of technology with broad access in many parts and has produced the amplitude of complementary production. This technology can further enhance its productivity via specialisations and economies of scale. Today, around 90 per cent of the world population have been subscripted to mobile cellular networks (ITU[1], 2012). According to the International Telecommunication Union's (ITU) estimations, net user penetration had covered 21 per cent of the population in developing countries, 71 per cent in developed countries and a mere 9.6 per cent in African countries by the end of 2012. It has been vastly acknowledged that ICT is increasingly influential in both social and economic developments. Using the Internet and access to broadband are in fact, akin to using basic substructures like roads and electricity; thus it is regarded as a general-purpose technology.[2]

Generally, the empirical investigation of economic growth and productivity usually distinguishes three impacts of ICT. The first effect is capital deepening as a result of investment, which, in turn, helps raise productivity and GDP growth. The second effect

[1] ITU, ICT data and statistics, http://www.itu.int/ITU-D/ict/publications/world/world.html

[2] See more information in section 1.2.5

is efficiencies of capital and labour or total factor productivity (TFP), which relates to quick technological advancement in the production of ICT goods and services. This consequently leads to increased return to ICT-producing sectors. Finally, a similar impact can also be attributed to the wider use of ICT throughout the economy as firms augment their general efficiency.

Furthermore, the increased use of ICT may contribute to network impacts by means of lowering transaction costs and encouraging speedier modernisation. Likewise, this improves the TFP. Such effects can be examined at diverse stages of analysis, i.e. with individual firm data, macroeconomic data or data at the industry level. The industry and aggregate level evidence supply cooperative insights concerning the effects of ICT, particularly on value added growth. However, it also raises questions concerning under which conditions does ICT growth become effective in enhancing value added growth for industries. Despite substantial investment in ICT, the industry and aggregate level evidence indicates extremely limited impact of technology on the productivity and growth in most countries. One probability is that computers remain invisible in the productivity data of many countries. For example, the Solow's productivity paradox [3] could have remained unsolved for some countries (Pilat, 2004; Solow, 1987). This productivity paradox will be discussed in detail in the subsequent sections.

Industrial level data may assist in explaining why ICT growth has led to greater economic effect. Certainly, it could indicate the impact on the contributory factors that cannot be observed at the aggregate level. In addition, the industrial level data can also make clear the competitive and dynamic effects that may come with the broadening of ICT. One example is the entrance of new industries and the exit of some failed

3The most common 'explanation' for the Solow paradox is offered by Jack E. Triplett (1999). It contains separate sections of evaluating for each position, and can be found at this address: http://www.jstor.org/stable/pdfplus/136425.pdf?acceptTC=true. In addition, we have completed the Solow residual explanation in chapter 3.

industries in the short and long run in contrast with industrial level and aggregate level evidence, which provides considerable information for countries affected by ICT-productivity, particularly in terms of their productivity and value added growth. Such evidence may also determine the consistency of the results on the aggregate and industry levels.

Industrial level evidence pertaining to ICT is now available in many developed countries (Pilat, 2004). This is attributed to the progress of the countries in the statistical development of ICT technologies, particularly on its various uses in the economy. Additionally, most Asian and several European countries are now able to collect industry level information on ICT and TFP contribution to value added. Combining these aggregate and industrial sources would be helpful in establishing new links between industry and macroeconomic performance, provided that the database is representative or includes a large portion of the economy.

1.2 Background of Study

The contribution of Information Communication Technology (ICT) to the resurgence of value added growth, as experienced in many developed countries, has attracted the attention of two groups – the economists and the policymakers. The discovery of relationships among economic growth, ICT, and Total Factor Productivity (TFP) growth has prompted a series of economic researches using different approaches. Among the earliest discoveries were the Solow growth model, Solow productivity paradox[4] and endogenous growth model.

The Paradox refers to economics that present negative or negligible productivity growth rates despite the evidence of large ICT and innovation investments in the country. This has been demonstrated in different countries and industries in recent decades. Hence,

[4]The Solow residual is explained in detail in chapter 3. See more information in chapter 3, Section 3.1.3.

ICT has been found to play both direct and indirect roles in the economic growth process. It is also believed to have an effect on ICT-producing, using industries and enhance productivity via its application (Badescua & Garce´s-Ayerbe, 2009). The massive and clear contribution of ICT to TFP and economic growth rose to an unprecedented level in 1987, when Robert Solow asserted that its contribution to organisational works remained vague or insignificant despite strong investments by the US companies. The reasons behind this paradox are further explained in the next sections.

The improvement of the endogenous growth models, which were generated by the research results of Romer (1986, 1990) and Lucas (1988) in the late 1980s, has encouraged further investigations on endogenous factors that influence economic growth. Lucas (1993), for instance, mentioned that the main engine for economic growth has been the accumulation of human capital. Therefore, human resources constitute a productive and dynamic stock. Each individual, by extension, is not only a factor of production, but also a life-long partner, a decision-maker and a trainable team-member.

Therefore, any work environment that enables human resources to access more ICT will enhance their communication abilities and learning productivity, which, in turn, will lead them to effectively become bigger in the existing stock of human factors. This kind of improvement is expected to affect economic growth significantly and it is for this reason that ICT investment attracts widespread attention among researchers. Among the results arising from the ICT revolution are the improvements in labour skills, the increased level of broad-based education and the motivation to consume. Consequently, an improved utilisation of ICT and TFP is encouraged in line with Solow’s argument that information access will improve faster if barriers are relaxed and investments are encouraged.

1.2.1 **Definition of the "New Economy"**

The "New Economy" is a well-defined concept. The term was established by the business press to describe a couple of wide trends around the world economy (Shepard, 1997). The first was business globalisation, which referred to the breakdown of socialism when capitalism spread around the world. This trend was market-driven with further trade deregulation trading then capital flows. Hence, multinational commerce and investment have assumed a significantly larger role in every country's economic plans compared to fifteen to twenty years ago (Jalava, 2003).

The second trend referred to the revolution of information and communication technology (ICT), which is the focus of this study. Such an advancement was driven by many forces, notably: (1) the immediate progressiveness in quality, (2) the fast fall in the prices of ICT products and software, (3) the convergence in telecommunications and computing techniques, and (4) the accelerated enhancement in network computing. This revolution seems to have continued ever since the advent of the transistor in the 1940s.

Henceforth, the price of computers declined sharply compared to fifty years ago. All these have supposedly justified what the "New Economy" is. Consider the following attributes as shown in Figure 1-1:

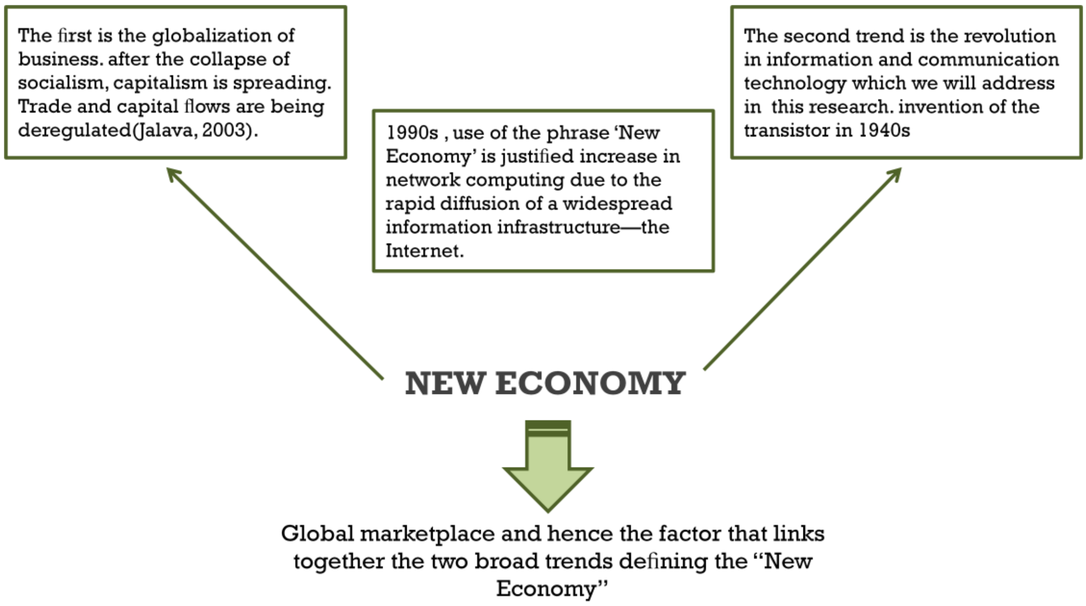

Figure 1-1. Trend of "New Economy"
Source: Developed by Jorgenson, 2011

Firstly, the technological breakthrough, which occurred in the mid-1990s, seemed to witness the semi-conductor manufacturing industry shifting from being an industry producing two-year cycle products to three-year ones (Jorgenson, 2001). Secondly, the emergence of the Internet infrastructure increased the use of network computing as it spurred rapid diffusion of information.

Hence, these two trends defined the "New Economy". To recap, the first was the globalisation of business, and the second was the revolution of information and communication technology. The Internet, in particular, becomes the tool to integrate markets and link people together across many sorts of conventional boundaries.

1.2.2 **Definition of Information and Communication Technology (ICT)**

The acronym ICT refers to two unconnected concepts: (1) information technology and (2) telecommunications technology. Information Technology (IT) is the phrase employed to explain the equipment and software program components that enable us to access, recover, save, organize, manipulate and exhibit information by electronic means. Communications Technology (CT), on the other hand, is the phrase employed to describe the devices, infrastructure, and software whereby information can be obtained and accessed (for example, phones, faxes, modems, digital networks, and DSL lines). ICT is consequently the result of the convergence of the IT and CT. One initial instance of ICT convergence is the crossing of the photocopy machine and telephone, leading to the creation of the fax. Above all, the clearest example in this area is the convergence of the computer and telephone, which resulted in the upsurge of the Internet.

In this study, we employ the definition of ICT by EUKLEMS (2010). Classification of ICT capital based on EUKLEMS databases are derived into three types; namely, communication equipment, computing equipment and software. Five core indicators on ICT infrastructure and access are introduced by the ITU, as part of a much larger collection of telecommunication indicators, Internet users, mobile-cellular telephone subscription, fixed telephone lines, fixed (wired)-broadband subscription and mobile-broadband (wireless) subscriptions.

For ICT assets, the gross rate of earnings is generally above other assets. This demonstrates the fast pace obsolescence of ICT assets. The rate of depreciation reveals the proportional loss of an asset's value due to the aging process, which includes not only the ageing influence but also the value change required by an increase or decline of the asset price, and even revaluation. In the present format, depreciation is a key component for the derivation of monitors of value-added. It determines income, net of the resources, which may have to be allocated to persevere with ICT and non-ICT capital services intact. Value-added follows the approach of disposable income for consumption. While not a suitable point of leaving for modelling producer behaviour, it offers a platform for the welfare point of view of economic growth. The particular attraction in this research is the impact of ICT contribution on the growth rate through the volume change in depreciation, since the latter is caused mostly by how much the volume changes in value-added (Colecchia & Schreyer, 2002).

1.2.3 **Definition of Total Factor of Productivity (TFP)**

One approach to consider the output of an economic system in which inputs are transformed, is through its production functions. This approach applies the econometric technique to relay on the output of a firm, industry, or economy to the inputs often noted as labour and capital. In the productivity research literature, the Cobb-Douglas functional form is pervasive. This production function has also been broadly used in earlier studies concerning the impact of ICT on the performance at the firm, industry and national level (Howitt, 1998). Therefore, we assume a Cobb-Douglas aggregate production function as follows:

(1.1)

$Y = A f(K, L) = A K^{\alpha} L^{1-\alpha}$

where '*Y*' is output or GDP, '*K*' is the aggregate capital stock that could be decomposed to ICT and non-ICT capital, '*L'* is the labour force, and $0<\alpha<1$ is the parameter of output share, demonstrating the elasticities of the production factors . '*A'* has been taken to be just a Solow[5] residual or the part of an economic factor of productivity that remains 'unexplained'. Using the production function from equation (1.1), '*A'* can be derived as:

(1.2)

$A = Y / (K^{\alpha} L^{1-\alpha})$

However, the endogenous growth theory challenges the conventional concept and started to call '*A'* as TFP. Now it becomes the engine of economic growth (Aghion & Howitt, 1997).

1.2.4 **What is the ICT– productivity paradox?**

Robert Solow stated that "computers were everywhere but in the productivity statistics" due to the studies that were conducted in the 1970s and the 1980s on the effects of

[5]The Solow residual has been explained in detail in chapter 3, section 3.1.3.

investment in ICT on productivity that revealed either negative or zero impact (Solow, 1987). Some evidence was found by recent studies concerning the considerable impact of ICT capital on the labour productivity, as compared to other forms of capital, which seemed to suggest that either TFP growth is positively impacted by the ICT or that ICT investments might have a spillover effect. Recent work on some specific OECD countries, such as the United States and Australia have categorically shown how total factor productivity and labour are enhanced by ICT (Gretton, Gali, & Parham, 2004).

In the last decade, there have been studies that have identified a number of factors that essentially contribute to the productivity paradox. Firstly, in the productivity statistics, there were some benefits of ICT that were not identified. Although most of the ICT investment is done in the service sector of an economy, there are difficulties in measuring the productivity in this sector. For example, the introduction of Automated Teller Machines (ATMs), which has improved the convenience of financial services is only looked upon as advancement in the financial services quality in countries. Similar problems plague other activities, such as health services, insurance and business services. Although in some sectors, as well as in some EU countries, progress has been made to improve the measurement, it remains a pivotal problem in judging the overall effect that ICT has on performance, especially in different countries (Triplett, 1999).

Secondly, it takes a considerable amount of time for the benefits of ICT use to emerge, making it hard to find evidence on ICT's impact. It is the same case with other key technologies; electricity is a good example of this. Often the dispersal of new technology is quite slow and it mostly takes a long time for the firms to adjust to all of them, e.g. in inventing or executing superior business procedures changing organisational arrangements or upgrading of the workforce. Furthermore, if it is assumed that TFP is raised by ICT, partly through the means of the networks that it provides, time is required for a network to be built that is large enough to have an impact on the economy. However, these effects have not been seen at equal levels in all the countries, and it is more pronounced in the United States compared to other countries. This suggests that other countries are still in the process of adjustment to the dispersal of ICT.

Thirdly, at the firm level, the attempts made to measure the effect of ICT in the early studies were actually established based on a small sample size of companies relative to the other studies, which were drawn from private sources. For instance, if ICT only had a small impact on performance, most probably only slight evidence would be found by such studies due to the econometric "noise", through which it can get lost. Another possibility is that the samples might not be representative, or the poor quality of the data. Furthermore, several studies have implied that it is important that there should be a distinction between the activities when the analysis is carried out, as the impact that ICT has on economic performance might differ from one activity to another. The studies that are most likely to find an impact of ICT are those that cover several industries and also have a large sample of official data, unlike the earlier studies. In recent years, a great deal of progress has been recorded in measuring ICT investment and the dispersal of ICT technologies, which implies that the series of data that is available is of greater quality and broader, and is more robust relative to the previous data.

1.2.5 **Is ICT a general – purpose technology?**

It is commonly argued that ICT is a "special" technology that affects a multitude of sectors and economic activities by making them productive. For this reason, a narrow definition of ICT investment would not capture the true impact of ICT on the economy. Often, ICT is considered to be a general-purpose technology (GPT). However, the idea of ICT representing a GPT is based on concepts associated with ICT investments that go beyond the notion of conventional capital equipment. In other words, it is perceived more as an "enabling technology" (Jovanovic & Rousseau, 2005). This may be true as knowledge becomes qualitatively and quantitatively more important than economic activities.

ICT facilitates communication and creates new knowledge via more efficient collaboration and information processing. In firms, this property of ICT can often be observed. Speedier information developing may perhaps enable firms to deal with new techniques of communicating with providers and arranging distribution platforms. As a result, processes can be reorganised and streamlined, which reduce capital needs through better utilisation of equipment and further reduction of inventories or space requirements. Increased communication reduces coordination costs and the number of supervisors required. A more timely and widespread transfer of information enables better decision-making and reduces labour costs (Arvanitis & Loukis, 2009; Atrostic, Boegh-Nielsen, Motohashi, & Nguyen, 2004; Gilchrist, Gurbaxani, & Town, 2001).

Lower communication and replication costs allow businesses to innovate by offering new products (Brynjolfsson & Saunders, 2009). Scholars interested in transaction costs consider communication technologies as capable of lowering the fixed costs of acquiring information and the variable costs of participating in the markets (Norton, 1992). The notion of new ideas or techniques that influence the economy on a broad basis was first published by Bresnahan and Trajtenberg (1995) who coined the phrase of GPTs. The main characteristics of GPT are as follows:

i) Applicability across a broad range of uses – “pervasiveness”;

ii) Wide scope for improvement, experimentation and elaboration, continuously reducing costs – “improvement”; and

iii) Facilitating further product and process innovations – “innovation spawning”.

In the case of spillover effects from ICT, its capacity to serve as a GPT is reflected in the dramatic decrease in ICT prices, leading to a substitution of ICT equipment for less productive assets (Jorgenson & Nomura, 2005).

Regarding the surge in the United States productivity during the period of the "New Economy", it was a consensus that strong IT investment was perceived as a driving force, where much of it originated from the ICT-producing sectors. Nevertheless, there is at least some indication that the efficiency gained from it has been spilling over to other industries that heavily use these new technologies as well. It is this characteristic that makes ICT likely to be a GPT, since, ultimately, computers and linked ICT equipment are expected to be utilised in most sectors of the economy as digitisation continues. Although it might be reasonable to claim that productivity gains from ICT can be found all around in daily business life, quantifying the spillover effect is difficult, as they are hard to isolate (Kretschmer, 2012).

This study intends to benefit policymakers by highlighting important accomplishments as an attempt to present quantitative indicators for measuring the role of ICT on GDP growth.

Bresnahan and Trajtenberg (1995) presented a line of study offering ICT as a general-purpose technology (GPT), which was based on the natural potential for 'technical improvements', 'pervasiveness', and 'innovation complementarities', thus, contributing more towards rising returns-to-scale (Brynjolfsson & Hitt, 2000). Similarly, David (1990) claimed that ICT has to be seen as widespread and general-purpose technologies that are certain to spread in the economic system and strengthen productivity growth, albeit with a lag. The exclusive value of ICT is the fact that by enabling essential changes in business processes and organizational structures, it may augment the TFP.

1.3 Statement of Research Problems

The work started by Romer (1986, 1990) and Lucas (1988) in the late 1980s concerning the development of the endogenous growth models kick started many empirical studies to explore and study the endogenous factors that are the determinants of economic growth. Accumulation of human capital has been consistently found across the studies to play a significant role as ‘‘the primary engine of growth’’ (Lucas, 1993). However, human capital is found to be quite a productive stock and dynamic as opposed to being static, as it is not as if each individual is just an inert worker, inasmuch as each individual is also a team-worker, a decision-maker, and a life-long learner. If the working conditions are improved by giving better access to information to people, and, at the same time, facilitating their communication abilities and learning productivity, then the current stock of human capital is effectively enlarged, while also enhancing its use.

Hence, there should be a positive impact due to these types of improvement on the economic growth. Given the preference to demand over supply, it is argued by Quah (2002) that improvements are fostered in consumer sophistication, improved level of broad-based education and labour skills through the revolution of Information and Communication Technology (ICT). In turn, this raises labour productivity and boosts the greater usage of technology, and, as a consequence, ‘‘drives economic growth, one way or another’’ (Quah, 2002). It is argued by Levine (1997) that by reducing the obstacles to information access, ICT is considered as a significant driver and encourages increased investment, which, in turn, promotes faster growth.

1.3.1 **Motivation of research concept and scope**

Until today, economists have fundamentally looked at the effect of ICT on economic growth and productivity within a neoclassical framework of ‘unilateral relationship’, in which ICT is supposed to correspond to other types of capital (Dimelis & Papaioannou, 2011; Inklaar, O'Mahony, & Timmer, 2005; Van Ark, Inklaar, & McGuckin, 2003). This approach, however, is relatively restrictive in fully capturing the impact of ICT. For this reason, we will conduct our econometric model by bypassing the assumptions of growth.

We will establish not only the contribution of ICT growth to productivity development, but to TFP, labour and non-ICT output growth as well. This we hope will fill the knowledge gap on causal relationships between the contribution of ICT, non-ICT, labour, Total Factor Productivity (TFP) and the value added growth rate. Moreover, there seems to be relatively very limited empirical studies pertaining to the impact of ICT on economic growth at the industrial and aggregate levels, specifically in the top ICT developed Asia-Pacific and European countries. There are inequalities in growth across countries and industries, which can be explained by the economic factors. However, what role does ICT play regarding this phenomenon?

The fact that fast and sustained progress is an inevitable characteristic of ICT makes this study crucial. Specifically, it attempts to capture the development of ICT and accurately calculate its effects on growth and the TFP, particularly in countries where its use is extensive, since, currently, the global trends for investment in telecommunications has become as large as that in energy (also see Figure 1- 2).

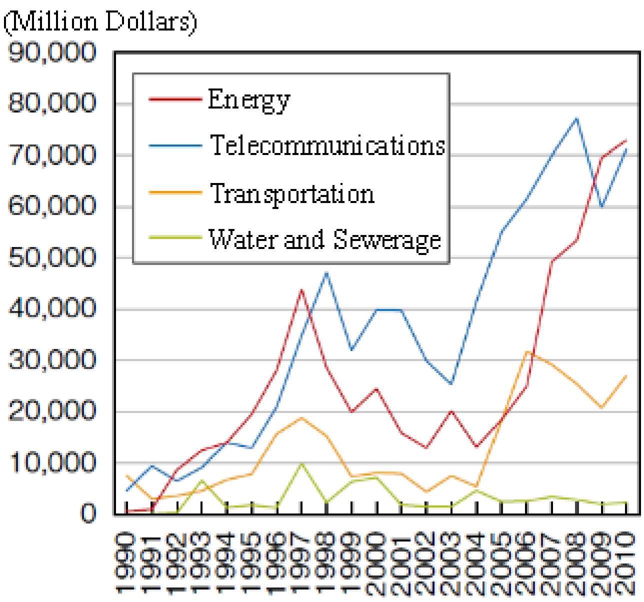

Figure 1-2. Worldwide investment by the private sector in infrastructure-projects
Source: White Paper on Information and Communications in Japan, 2012

The exploratory role of ICT at the sectoral and aggregate levels raises some difficult questions that we intend to answer by classifying the literature according to the firm, industry and aggregate levels. The discussion suggests whether aggregate evidence or industry level data may cause an apparent productivity paradox. Some European countries besides the Asian countries may have not yet benefited from the spillover effects that would generate a wedge between the impacts observed on individual industries and those at the macroeconomic level. According to previous studies, the results may vary depending on the duration, area, and type of sector involved. Therefore, the manifesting productivity paradox between a few Asia-Pacific and EU countries will complete the research chain in this area.

Enhancements in measuring data have performed a significant role in building up the evidence of the effects of ICT. Most of the previous work with the industrial data on ICT and productivity was influenced by different data sources. However, sources from individual countries have a number of methodological drawbacks. Firstly, often, the data do not represent a fixed sample of industries, indicating the possibility of biased conclusions being drawn. Furthermore, scientific studies depending on specified sample of industries will tend to disregard dynamic impacts, just like the entrance of new players or the demise of existing ones, which might accompany the extent of ICT. Secondly, the quality and comparability of individual country data sources are questionable, as they are not necessarily verified by international statistical conventions, measures or definitions.

Indeed, the benefits of industry level analysis and the aggregate level effects of ICT are materialised in the form of longitudinal databases in international statistical offices. Among the first were the databases of the EU KLEMS and World Bank Indicators (WBI). These databases are more extensive and statistically more representative samples compared with those available in individual country statistical centres. The availability of such data is imperative given the enormous data for the industry performance of countries. Furthermore, they allow industries to be tracked over time and could be correlated to other research and data sources.

1.3.2 Motivation on methods

Most previous studies viewed the association between ICT, TFP and economic development in different nations or periods. However, essentially, this relationship, fails to imply a causal relationship, particularly when non-stationary time series variables are not cointegrated. In particular, the Granger causality test allows us to identify the directions of causality and establish whether ICT growth results in GDP growth, or vice versa, and/or whether a spillover effect through TFP growth is present between the two. This spillover effect of ICT under the endogenous growth framework, particularly in the aggregate panel data section, is distinguished by employing controlling variables. However, due to the discriminated sectoral effects of ICT on value added growth, particularly at the macro-level, we will analyse the pooled mean group using the generalised method of moment under the growth-accounting framework.

Despite being resource intensive, panel data analysis allows scholars to achieve a deeper understanding of the effect of ICT contribution on growth. As Kohli and Devaraj (2003) suggested, using larger samples including cross-sectional or panel data can assess the impacts of ICT payoff correctly. Such samples can frequently enhance the accuracy of the econometric analysis, because, through using these data, country (industry) specific effects can be controllable. Applying this sort of data also permits the researcher to observe the lag effects of ICT impact. This is an advantage, as ignoring lag effects has been cited as a factor that contributes to GDP growth (Gholami, Sang-Yong, & Heshmati, 2006). Using pooled time series studies with cross-sectional also has been able to answer some specific questions to be answered. For example, we could classify whether the relationship between variables is in the short or long run.

1.4 Scope of Research and Data

The main purpose of this study is to exploit the comprehensive ICT effects on economic growth with regards to the top ICT developed countries in Asia-Pacific and Europe. To fulfil this objective, we collected the aggregate level data for the 12 top ranked ICT countries in both regions from the World Bank Indicator database. Annual data collected between 1990 and 2011 served as the secondary data. The countries listed in the EU are Sweden, Iceland, Denmark, Finland, Luxembourg, and Switzerland while those in the Asia Pacific include Korea (Rep), Hong Kong, New Zealand, Japan, Australia, and Singapore. At the aggregate level, estimation methods were applied to the following variables (Table 1-1) as part of the research.

Table 1-1. Descriptive of variables used in aggregate level section

EG	"GDP growth (annual %)"
L	"Contribution of Labour Composition Index to GDP Growth (annual %)"
ICT	"Contribution of ICT Capital Services to GDP Growth (annual %)"
Non-ICT	"Contribution of Non-ICT Capital Services to GDP Growth (annual %)"
TFP	"Total Factor Productivity Growth (annual %)"
ICT-IM	" ICT Goods Imports (% total goods imports)"
PTN	" Patent Applications, Non-residents"
PTR	" Patent Applications, Residents"
TERIT	" School Enrolment, Tertiary (% gross)"
HT	" High-Technology Exports (% of manufactured exports)"
UPL	" Unemployment, Total (% of total labour force)"
EXP	" Exports of Goods and Services (% of GDP)"
IMP	" Imports of Goods and Services (% of GDP)"

Source: World Bank Indicator Database, 2011

However, collecting comparable data at the industrial level posed some limitations. Among the top six ICT developed countries, as listed in Table 1-2, we only managed to cover Japan and Australia using the EU KLEMS database. Hence, the industrial level data was only derived from the unique EU KLEMS database for two reasons. First, often, individual country data often does not derive from a representative fixed sample of industries and further suffers from a number of drawbacks in the methodological parts of the research. This may imply that the results of such studies are biased, and, hence, may not be comparable. Second, the comparability and quality of individual country data sources are generally unknown, whereas the data are not essentially verified by international statistical conventions, procedures or definitions.

For the top six EU zone countries, as listed in Table 1-2, we only succeeded in gathering data from Sweden, Denmark, and Finland. Nevertheless, these countries are among the top ranked according to the International Telecommunication Union (ITU) in 2011. To ensure precision, we used the EU KLEMS database as the unique database in order to capture a highly reliable set of data.

Table 1-2. Six top ranking of ICT development index (IDI) among EU and Asia-Pacific countries

European Economy	Regional Rank 2010	Global Rank 2010	Asia-Pacific Economy	Regional Rank 2010	Global Rank 2010
SWEDEN	1	2	KOREA(REP)	1	1
ICELAND	2	3	HONG KONG	2	6
DENMARK	3	4	NEW ZEALAND	3	12
FINLAND	4	5	JAPAN	4	13
LUXEMBOURG	5	7	AUSTRALIA	5	14
SWITZERLAND	6	8	SINGAPORE	6	19

Source: International Telecommunication Union (ITU), 2011

The listed variables applied to the industrial panels are as illustrated in Table 1-3.

Table 1-3. Descriptive of variables used in industrial level section

EG	Growth rate of value added volume (% per year)
L	Contribution of hours worked to value added growth (%)
ICT	Contribution of ICT capital services to value added growth (%)
Non-ICT	Contribution of non-ICT capital services to value added growth (%)
TFP	Contribution of TFP to value added growth (%)

Source: World Bank Indicator Database, 2011

The most relevant characteristic of the EU KLEMS database is the high degree of harmonisation it exhibits with the agreed criteria used to compute information. This guarantees data consistency across countries. Industry classification, input and output definitions, price deflators, labour qualification criteria and definitions of capital services have been unanimously agreed as criteria that make a particular set of data fully comparable between industries and countries.

Table 1-4. List of industries

List of Industries	Number
Agriculture, hunting, forestry and fishing	1
Mining and quarrying	2
Food, beverages and tobacco	3
Textiles, textile, leather and foot wear	4
Wood and of wood and cork	5
Pulp, paper, printing and publishing	6
Chemical, rubber, plastics and fuel	7
Other non-metallic mineral	8
Basic metals and fabricated metal	9
Machinery, NEC	10
Electrical and optical equipment	11
Transport equipment	12
Manufacturing NEC; recycling	13
Electricity, gas and water supply	14
Construction	15
Wholesale and retail trade	16
Hotels and restaurants	17
Transport and storage and communication	18
Post and telecommunications	19
Finance, insurance, real estate and business services	20
Community social and personal services	21

Source: World Bank Indicator Database, 2011

Another relevant feature of the dataset is the high level of sectoral disaggregation it presents. For example, data for 71 industries have been produced in the most recent period with the level of detailed data varying across countries, industries and time periods. Although they are available from 1970 onwards, this study focuses on data obtained from 1990 to 2007.

Moreover, we used 21 sub-sector industrial data for the five countries mentioned earlier in Table 1-4. The classification of Table 1-4 also provides the capability for future comparability researches with EU member and non-member countries. Analysis based on comprehensive industrial categorisation provides a superior view concerning the productivity and growth of ICT's consuming and producing industries (Fukao, Miyagawa, Pyo, & Rhee, 2009).

1.5 Research Questions

This research is premised on six main questions:

1. What was the contribution of ICT growth to economic growth cross-country over the last two decades? (Linked to Hypothesis 1)
2. Did ICT-producing industries experience a higher return growth than the ICT-using industries between 1990 and 2007? (Linked to Hypothesis 2)
3. Is there a long run co-integrating relationship between output, TFP, labour employment, ICT capital and non-ICT capital? (Linked to Hypothesis 3)
4. What is the direction of the causal relationship between ICT, TFP and EG in selected countries within industries over the short run and long run periods? (Linked to Hypotheses 3, 4 and 5)
5. Was there any complementary effect between ICT and non-ICT capital in the selected countries over the 1990-2011 period? (Linked to Hypothesis 5)

6. Do less developed ICT countries receive higher spillover effects of ICT than the highly developed countries? (Linked to Hypothesis 6)

1.6 Objectives of Study

This study sets out to achieve the following objectives to address the problem statements and research gaps:

1. To assess the ICT contribution effects on economic growth in ICT-producing and ICT-using industries based on growth accounting and endogenous growth model (Link to research questions 1, 2).
2. To verify direction of causality between economic growth, and contribution of ICT and TFP growth in long-run and short-run cross-countries (Link to research questions 4).
3. To investigate the long-run relationship between labour employments, output growth, ICT and non-ICT in cross-countries and industries (Link to research questions 3, 6).
4. To verify differences of ICT spillover effects in high developed ICT Asia-Pacific countries and EU countries (Link to research questions 5).

1.7 Research Hypotheses

The open economy with extensive export and import activities via the ICT, when viewed at the macro level along with an enhanced TFP, have changed the scale of the economy by raising its output level. Therefore, despite the direct ICT capital impact, its spillover effect on value added growth has led us to the following hypotheses.

1. ICT capital is the main source of economic growth against non-ICT capital.

2. The ICT-producing sector has a higher significant positive spillover effect on value added growth than ICT-using sector.

3. There is a bi-directional association between ICT contribution and economic growth in selected countries and industries. (ICT $\leftrightarrow$ EG).

4. There is a uni-directional relationship between ICT growth and TFP growth in selected countries and industries. (ICT $\rightarrow$ TFP).

5. There were no significant complementary effects between ICT and non-ICT capital between 1990 and 2011.

6. ICT has a higher positive spillover effect on value added growth through TFP in highly developed countires than less developed countries according to the ICT development index.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The relationship among ICT, TFP, and economic growth has been researched by numerous past studies. In essence, such an association follows along three main streams. The first stream concerns studies that explored the ICT spillover effects on growth through different approaches at the firm, industry and macro levels. The second stream links the contribution of ICT to economic growth at the aggregate level data that are classified according to specific and multi-country analysis so that a meaningful comparison can be made. The third stream relates to the causality literature of ICT, GDP growth and productivity. We have illustrated this classification in Figure 2-1.

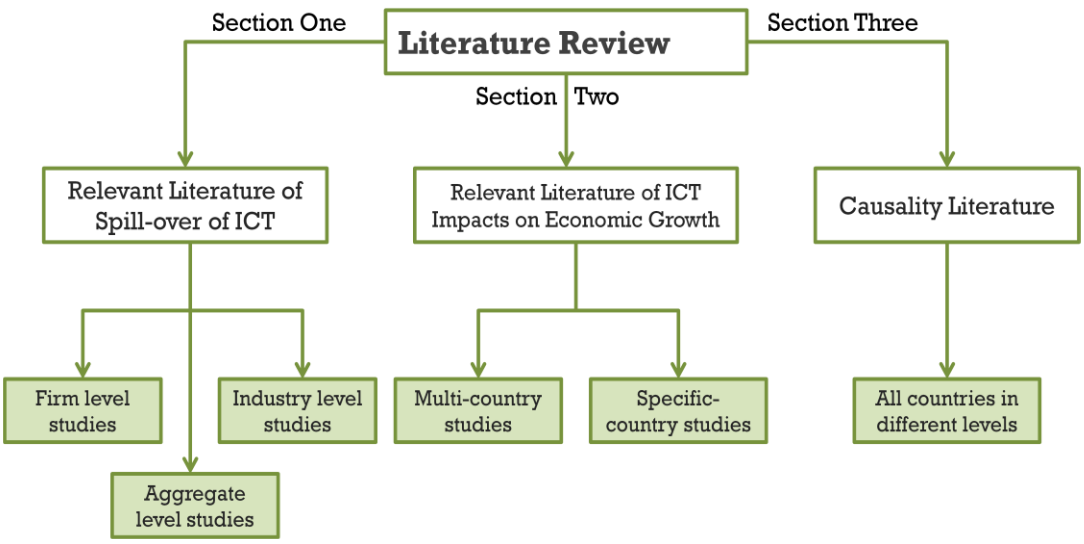

Figure 2-1. Classification of literature review
Source: Author, 2013

The literature review process offers a useful means to analyse relevant studies by making taxonomy in cross-country and cross-industry streams. The integration of these fields enables us to generate a balanced perspective of the current state of the contribution of ICT to both TFP and economic growth.

2.2 Relevant Literature concerning the Spillover of ICT at the Firm, Industry and aggregate Levels

'Spillover' refers to the economic impact of ICT investment. By definition, it is an increase in social welfare without compensation to the investors (Gholami, 2006). According to 'endogenous growth models', innovation is a medium for technological spillovers that enables less developed countries to catch up with the well-developed ones. On the other hand, ICT capital seems to be characterised by forms of capital, traditional forms of capital as a production technology and knowledge capital in its informational nature (Dedrick, Gurbaxani, & Kraemer, 2003).

One key argument over the existence of the spillover of ICT is whether its capital stock may also enhance economic growth towards TFP, particularly if the capital resembles knowledge capital. The resources for economic growth may be relatively different over time and across countries. However, innovation and technological changes have been mainly approved as the determinants of growth. In addition, ICT has been considered as the main form of technological transformation in recent decades (Madden & Savage, 2000). Dedrick et al. (2003) identified the ICT spillover effects as an opportunity for future research. Table 2-1 in a condensed form, illustrates the recent findings on the relationship between the ICT spillover effects on TFP growth at the firm, industry and aggregate levels.

Table 2-1. Summary of empirical studies on ICT spillover effects on TFP at the firm, industry and national levels

Authors	Period	Case Study	Method
Firm Level Studies			
Arvanitis (2004)	1990-1993	Switzerland	Labour productivity regressions
Atrostic et al. (2004)	2000	Denmark, Japan, US	Labour productivity regressions
Gretton et al. (2004)	1998	Australia	Labour productivity regressions
Motohashi (2003)	1999	Japan	Production function, TFP
Mariela Badescua (2009)	1994-1998	Spain	Cobb-Douglass PF
Maliranta et al. (2008)	2008	Finland	Production Function
Industry Level Studies	**Period**	**Case Study**	**Method**
Hans-Jürgen Engelbrecht (2006)	1988-2003	New Zealand	GLS[a]
Diego Martínez (2010)	1980-2004	US	Cobb-Douglass PF
Dimelis & Papaioannou(2011)	1990-2000	US, EU	GMM[b], panel data
Dahl et al.(2011)	1970-2004	Japan, EU-US	GMM[b]
Stiroh (2002)	1948-1999	US	Growth accounting
Dedric et al. (2003)	------	More than 50 research papers	A Critical Review of the Empirical Evidence
Michael J. Harper (2010)	1987-2006	US	Growth accounting
Fueki & Kawamoto (2009)	1975-2005	Japan	Growth accounting
Engelbrecht & Xayavong (2006)	1988-2003	New Zealand	Difference-In-Difference Regression
Mc Morrow et al. (2010)	1980-2004	US, EU	ECM[c]
Kretschmer (2012)	-------	OECD countries	Review of on dynamic, macroeconomic effects of ICT
Aggregate Level Studies	**Period**	**Case Study**	**Method**
Ketteni et al. (2007)	1980-2004	OECD	Nonparametric techniques
Hwan-Joo & Young Soo (2006)	1992-1996	38 countries	GLS
Elsadig Musa Ahmed (2008)	1960-2003	Malaysia	Parametric model
Jalava (2003)	1975-2001	Finland	Growth accounting
Jalava & Pohjola (2002)	1974-1999	US, G7	Comparison study
Jalava & Pohjola (2007)	1995-2005	Finland	Production function
Christopher Gust (2004)	1992-1999	Industrial countries	Pooled regression estimates
Esteban-Pretel & Nakajima (2010)	1980-1990	Japan	Neo-classical growth
Dahl et al (2011)	1970-2004	Japan, EU-US	GMM[b]
Bloom, Sadun et al. (2007, 2012)	1995-2003	US	Micro panel datasets, production function
Antonelli & Quatraro (2010)	1970-2003	12 major OECDs	Growth accounting, Cobb-Douglas PF

Note: [a] GLS: generalized least squares model, [b] GMM: generalized methods of moments approach, [c]ECM: Error Correction Mechanism specification

Source: Author, 2013

2.2.1 Firm level studies

As opposed to the aggregate and sectorial level analysis of ICT's economic impacts, firm level analysis is characterised by an extensive variety of methods and data. This is partially due to the basic differences among the data. In fact, it also implies that an extensive variety of approaches can be applicable to firm level data. Such diversity of empirical evidence, being derived from different methods is considered stronger. This is unlike cross-country comparisons, where there is a requirement for comparable data and common methods.

According to the recent firm level studies, it was found that firm performance could be impacted positively through the use of ICT. However, to a certain extent, the results vary. Among the most notable results was that ICT-using the productivity performance of the firm tended to be much better. In particular, the labour productivity of those firms using one or more types of ICT was much higher than the firms that did not use ICT. Furthermore, between 1997 and 1998 there was an increase in the gap between the firms that used technology and the ones that did not, as there was an increase in the relative productivity of firms using technology as compared to non-users (Pilat, 2004).

Australia is the fourth ranked ICT-developed country in the Asia Pacific region in which technology has already had a significant impact (Gretton, Gali, & Parham, 2002). In particular, Gretton, Gali and Parham (2002) found that both aggregation of firm level and aggregate growth accounting have resulted in ICT, together with its related impact, raising Australia's TFP growth by approximately 0.2 per cent. Most significantly, the econometric analysis at the firm level, which is controlling other impressive factors, established positive links between productivity growth and ICT use for all the industrial sectors examined. The results found in Australia have been confirmed by many studies, such as Arvanitis and Loukis (2009) in Swiss and Jovanovic and Rousseau (2005) in Finland, among others. Correspondingly, they found that productivity is closely correlated to ICT use.

Badescua and Garcés-Ayerbe (2009) carried out a survey on Spanish firms where they investigated the impact of IT on the productivity of labour using firm level representative panel data. The survey involved 341 medium and large-sized firms. They specifically employed the Cobb-Douglas production function to quantify the contribution of information technology capital to labour productivity. Significantly, the findings not only related to firm-specific, but corrected period-specific effects as well. One explanation for this is that judging from the fact that ICT's positive effects only emerge after a long time, there is a huge lag between the education process and the performance of new technologies.

A similar study in Finland (Maliranta, Rouvinen, & Airaksinen, 2008) involved controlled time and industry effects. In particular, the researchers found that the impact of ICT on the range of labour productivity, from 8 per cent to 18 per cent, corresponds to 5 to 6 per cent elasticity of ICT capital. The effect is more pronounced in ICT-producing services and new firms. With reference to this point, a study was conducted by Atrostic et al. (2004) to examine the effect of computer networks in Japan, the United States and Denmark (three OECD countries). Particularly, in Japan, it was concluded that the usage of both inter-firm and intra-firm networks at the firm level was positively correlated to the TFP levels. This is in line with the findings of Motohashi (2003). In particular, Motohashi (2003) confirmed the establishment of a positive coefficient for several types of network, including Electronic Data Interchange (EDI) and open networks (Internet).

To sum up, the studies at the firm level discussed above demonstrated that productivity is significantly improved by ICT, as is evident from its economic impact, but that it is by no means a simple task to essentially convert the investment done in ICT into greater productivity. Normally, changes in complementary investments, such as firm age and size, organisational change, innovation and human capital are also required. It has already been suggested in the discussion above that the effect of ICT may be greater than the direct return effects flowing to firms that are ICT-producing and ICT-using (Pilat, 2004).

2.2.2 **Industry level studies**

The literature review of ICT contribution has shown that in contrast to aggregate level studies, industry level studies have been more conclusive. Aggregate level studies have suffered due to the limitations present in their analysis. For example, a positive correlation was found between economic growth and ICT at the country level in the Asia-Pacific region (Dedrick, Gurbaxani, & Kraemer, 2003). However, the researchers did acknowledge the lack of conclusive proof regarding the causal relationship due to the comprehensive range of factors that affect economic growth, and also because the economic allocation to ICT is relatively small in the overall capital.

To this point, it has been concluded that the use of ICT in portions of the services sector is more widespread than in manufacturing albeit the same technology is not used by all the sectors. Financial services is considered to be among the most ICT-intensive sectors in many countries (Kretschmer, 2012). Among the OECD countries, the financial intermediation sector was found to be the most likely sector to use network technologies (OECD, 2003), which is an indication that this sector most probably profits from ICT and that it is a considerable consumer of information.

There is a lack of evidence supporting the argument that the services sector has seen strong performance growth due to the use of ICT at the industry level with the United States and Australia being the exceptions (Kretschmer, 2012). In some cases, it has been observed that the performance of the service sector can be enhanced by the use of ICT at the firm level, more so in countries where there is slight proof of accessibility at the industry level. As for the case of the United States and Australia, the industry level evidence was confirmed by studies conducted at the firm level (Gretton, Gali, & Parham, 2004). Maliranta and Rouvinen (2008), and Arvanitis (2009) in Finland and Switzerland proved that in the manufacturing sector the Internet does not play an important role in terms of performance as compared to the service sector. This is probably due to the lack of desk job work, personal computers and Internet connections for the manufacturing workers.

Atrostic et al. (2004) used the Badescua and Garcés-Ayerbe (2009) method for New Zealand at the industry level but that they did not obtain similar results, which proves that the results are sensitive to the time period specified. Engelbrecht and Xayavong (2006) used the breaking period of the study approach sub-periods over 1988-2003 to support that labour productivity growth of ICT intensive industries has improved more than for other industries, albeit the overall labour productivity growth was weak.

The dynamic general equilibrium approach on US industries revealed the same as New Zealand's results, which have shown the sensitivity of productivity growth from ICT on the time specification (Engelbrecht & Xayavong, 2006; Martínez, Rodríguez, & Torres, 2010). As a result of the interpretation, it can be concluded that there is a large gap between the learning and running operation of new technologies, which indicates that its positive impact on the firms emerges after a moderately long period of time. In 2002, the Federal Reserve Bank of the US published a surprising result from a broad survey about the effect of TFP and labour productivity (APL) growth on the ICT- producing sectros in the US manufacturing industries. The results of this comprehensive research revealed that the neoclassical framework identified five different input measurement errors, i.e. omitted variable, increasing return, reserve causality, production spillover and network externalities, that have an existing correlation between ICT and TFP growth. The data collection for TFP was first completed by the Bureau of Labour Statistics (BLS) in the United States and then APL and TFP[6] were estimated by using equations (2.1) and (2.2) (z: proxy) for the two main digital manufacturing industries.

(2.1)

$dLn\ APL = dLn\ Y - dLn\ H$ APL growth

[6]TFP growth is defined as output per all inputs, and ALP growth is output per hours worked. See the discussion of productivity in the July 2001 issue of Business Economics for details.

(2.2)

$dLnZ = dLnY - \alpha_k \, Ln\, K - \alpha_H \, Ln\, H - \alpha_M \, Ln\, M$ TFP growth

Where Y is output growth, H is human resources, K and M, non-ICT and ICT capitals. Therefore, the dLnZ is measured as a residual to fulfil the equality. This model is estimated in the neoclassical model based on Solow's (1987) and Jorgenson's (1987) assumptions of the growth model (Stiroh, 2002a, 2002b).

Other scholars extended Stiroh's approach by adding more observations; Harper, Khandrika, Kinoshita, and Rosenthal (2010) for the US industries, and Fueki and Kawamoto (2009) for the Japanese industries, which have addressed negative coefficients for ICT as a non-impressive factor. In contrast with Sitroh's (2002a) results, another research established the contribution of ICT-specific technological changes in productivity growth that was about 0.73 per cent, while non-ICT capital assets were only 0.16 per cent. It is noteworthy to mention that the contribution of ICT has increased from the mid-1990s while the contribution of non-ICT capital inputs has decreased (Martínez et al., 2010). For a better understanding of this surprising result, Stiroh (2002b) decomposed ICT into computers and telecommunications equipment and then estimated them again. The findings revealed the existence of considerable differences between the two types of equipment of ICT and heterogeneity in productivity shock across industries.

Identifying the determinants of the TFP growth gap using industrial level data for the US and EU using the panel data approach was carried out by McMorrow, Röger, and Turrini (2010), and Dimelis and Papaioannou (2011). In the previous studies, TFP growth was significantly fuelled by developments at the "technological frontier" since the 1990s for both the US and the EU. Moreover, TFP growth in the US was stronger than the EU at the end of the 1990s due to more Research and Development (R&D)

expenditure and upper adoption rates for ICT intensive technologies. Mc Morrow et al. (2010), employing Least Squares Dummy Variables (LSDV), and Dimelis & Papaioannou (2011), using Pooled Mean Group (PMG) and Generalised Moment of Method (GMM) estimators, claimed that the ICT impact on productivity was primarily exhibited in the industries that were either heavy ICT users or producers and stronger network utilities. Recent efforts were made by the EU zone to investigate the connection between TFP growth and ICT in cross-industry and cross-country simultaneously (Dahl, Kongsted, & Sørensen, 2011). To sum up, the results of the EU and the US studies arrived at a common conclusion that due to ICT's slow adoption in the EU industries, the EU has limited acceleration of productivity and economic growth. Comparatively, the US has seen its productivity grow faster than the EU because the ICT-producing sector had a larger employment share and the rapid productivity growth of the services industries extensively utilised ICT.

Cross-industry studies regarding the ICT's productivity or spillover effects are relatively quite rare, mainly due to comparable data sources being fairly new. To sum up, the results for the industrial level are more concerned with the US due to the slow adoption of ICT in the EU industries. Furthermore, industries that produce or use ICT most intensively have shown the largest increases in productivity growth after 1995 (Stiroh, 2002a, 2002b). Nevertheless, there is little evidence that rapid TFP growth has been experienced by ICT-using industries, with the major exceptions being Australia and the United States (Pilat, 2004).

2.2.3 **Aggregate level**

Difficult questions are raised when the role of ICT is examined at the firm, sectoral and aggregate levels, which we are trying to address by classification of the literature according to the firm, industry and aggregate levels. There is little evidence that at the industrial level more total factor productivity growth has been experienced by ICT-using, with the major exception being Australia and the United States (Pilat, 2004).

The wedge among the impacts observed at the macroeconomic level and those for industrial and individual firms, which could be created by the spillover effects, may not yet have been beneficial for some European countries. It has been argued that the impact of direct returns flowing to the ICT-using industries and firms may be less than the impact of ICT. For instance, there could be an improvement in the functioning of the markets (through the process of improved matching) and there is a possibility of making new markets, which could be due to the lower transaction costs of ICT. The impact of ICT on innovation and knowledge creation is another effect that could potentially create a gap between the aggregate returns and firm-industry level returns. The process of knowledge creation could be increased through the use of ICT, as it facilitates the processing of data and information at a greater speed. These kinds of spillover effects may have already been highlighted in the United States aggregate statistics, but this is not the case in other countries thus far.

Moreover, the impact of ICT in aggregate and sectoral analysis might be disguised due to the effects on economic changes and the aggregation across industries and firms. This is also due to the dependence of the impacts of ICT on policy changes and other factors, which might vary across industries. The scope of the aggregate effects over a period of time is dependent on the rate at which ICT develops their lags, diffusion, adjustment costs, complementary changes and ICT’s potential of productivity-enhancement in diverse industries (Gretton, Gali, & Parham, 2004). It is by no means a straightforward task to disentangle such factors at the industry or aggregate level.

Concerning the evolution of TFP for 38 countries, Hwan-Joo and Young (2006) suggested that the digital divide, on the one hand, widens the growth gap among countries, which is the negative impact of ICT-using. On the other hand, the global ICT diffusion generates ICT externalities, which have a positive effect on the total factor productivity of less-developed countries.

The results for Malaysia, as an Asian economy, revealed that the increasing knowledge of the labour factor has a significant effect on the performance of TFP in respect of economic growth (Elsadig, 2008). The impacts of ICT and human capital on Malaysia's productivity growth have been highlighted and the results have been adopted by policymakers. The log-linear based model is used, which measures the elasticity of variables, the autoregressive regressor estimated labour productivity factor (APL) growth into contribution of capital deepening (K/L), increasing ICT usage (ICT/L), human capital intensity and TFP per unit labour growth between 1960 and 2003. The findings of Elsadig (2008) for Malaysia support the study of Martínez et al. (2010) that APL significantly influences capital deepening. In contrast with the linear relationship between these variables, Ketteni, Mamuneas, and Stengos (2007) also proved the existence of a nonlinear relationship between the mentioned variables by using nonparametric techniques for members of OECD during 1980-2004.

Based on the results obtained in Finland and the US, which are considered leaders in information societies with respect to Nokia's revolution in the telecommunication industry Finland has demonstrated that the contribution of ICT is 1.87 per cent of the monitored labour productivity growth. Despite the fast growth of TFP in the ICT-producing industries, it has had an even larger impact on Finland; however, in the US, there has been no evidence of any significant acceleration in the rate of labour productivity (Jalava, 2003; Jalava & Pohjola, 2002, 2007).

However, Jalava and Pohjola (2007) argued that ICT could increase the economic growth via the spillover effects of ICT through to TFP. In the suggested model, the aggregate input consisting of ICT capital services (K_{ICT}), other capital services (K_O), and labour services (L) produced total outputs under equation (2.3).

(2.3)

$$Y\ (Y_{ICT}\ (t),\ Y_0\ (t)) = A\ (t)\ F\ (k_{ICT}\ (t),\ k_0(t),\ L(t))$$

It is of interest to compare the European evidence to the US results in this research. In this respect, four other related papers by Gust and Marquez (2004), Pilat (2004), Esteban-Pretel, Nakajima, and Tanaka (2010), and Dahl et al. (2011), captured the general consensus about productivity growth performance in the EU economies that was mostly described by an unpromising performance of the ICT-using industries. These studies provided evidence, especially for high, middle income, European countries and the US. They created a perspective that can be used to measure productivity divergence between European industrial countries and the United States by stressing the role of managing practices in influencing the diffusion of ICT.

According to the above studies, ICT has a positive effect on productivity growth in Europe; nonetheless, the effects found for the US are more than twice the effects found for Europe. To some extent, the divergence in productivity levels between the two regions is due to the difference in the utilisation of ICT; however, the decline in the European productivity growth after 1995 is not explained by this. Regardless of the positive effects that ICT has on productivity growth, European productivity growth is still declining. Therefore, there was a decrease in Europe's aggregate and industry averages of productivity growth after 1995. One reason as to why there was greater growth performance of ICT in the US economy to that of non-US countries was put forward by Bloom, Sadun, and Reenen (2007, 2012), and Pilat (2004). The authors presented evidence pointing towards the US management style practices that relate to ICT being used more productively.

They mentioned an unresolved and a very important issue concerning where study on the effects of ICT on TFP growth was done using two different approaches and which generated different results. Significant and positive effects were found for TFP growth when production functions were estimated post-1995. In contrast, some of the results have applied a traditional growth accounting background that shows no significant productivity growth acceleration in Europe and OCED countries because of the delay in technology adoption compared to the US. Both approaches apply different restrictions, which may be the likely cause of the difference found (Antonelli & Quatraro, 2010).

Another suggested reason for this divergence is that the success of the countries in implementing ICT may be down to the ability to gain market share and growth in competitive markets, the United States as compared to less competitive markets. Consequently, there would be a greater contribution to the overall impact of ICT in the US. Moreover, there is an active role of competition in determining the effect size of the spillover. In a competitive market, which is quite large and highly intensive, as in the United States, the largest beneficiaries of investment in ICT may not be the firms using ICT but the effect on the aggregate performance of the country (Pilat, 2004).

Finally, the most important reason for this difference can be due to the measurement playing a role. In most countries, sectoral and macroeconomic data may be insufficient to identify the impact of ICT due to the different ways output is measured. For instance, the convenience brought about by the introduction of automated teller machines has led a few countries to change the way banking output is measured, as in the United States. As the primary user of ICT is the services sector, it would be a considerable problem if there is a difficulty in measuring service output.

In conclusion to this part of the literature, the most widely used approach to estimate the spillover effects of ICT have been industry or firm level data usage. The comparison between the results obtained from the studies done on European countries and the United States is particularly interesting. According to the above, there is a positive spillover effect of ICT on productivity growth in Europe; nonetheless, the effects found in the US are more than twice that of Europe. As a justification to this profound difference, many reasons have been suggested by previous studies. It is interesting to investigate Asia-Pacific countries, which are leaders in ICT development and also followed the EU productivity paradox after 1995. Furthermore, the presented discussion showed that aggregate evidence might lead to an apparent productivity paradox in the EU whereas there is little evidence of the paradox for the industry and firm level data used.

2.3 Relevant Literature concerning the impact of ICT on Economic Growth

Recent theories concerning economic growth predict that economic growth depends on investment in ICT. Nevertheless, empirical studies have suggested combined results based on the region, the time period and the type of industry considered. Moreover, some surveys support that the growth gap between the developed countries and underdeveloped countries is associated with the ICT diffusion and the productivity and growth rate of those countries. This part of the literature has been surveyed under two processes, namely, multi-country literature surveys and specific individual countries.

2.3.1 **Multi-country studies on ICT – economic growth nexus**

Table 2-2 presents the chronological list of empirical works conducted on the association between ICT contribution and economic growth based on authors, time frame, country, and methodology in multi-country and specific-country streams.

In a joint study, Hosseini Nasab and Aghaei (2009) considered the economy of OPEC member countries between 1990 and 2007. The long run growth of the economy with the neoclassical model of capital accumulation, as well as using the dynamic panel data framework and employing a Generalized Method of Moments (GMM), found a significant impact of ICT investment on economic growth (Mankiw, Romer, & Weil, 1992).

Table 2-2. Summary of multi-country and specific-country empirical studies on ICT – economic growth nexus

Authors	**Period**	**Case Study**	**Method**
Multi-country studies			
Hosseini Nasab & Aghaei (2009)	1990-2007	OPEC member	GMM
Lam et al., (2010)	1980-2006	Selected countries	GMM
Gholami et al. (2009)	1996-2004	37 countries	Cobb-Douglass PF
Cortés & Navarro (2011)	1980-2007	27 European	Growth accounting
Tseng (2009)	1976-2006	6 ASEAN	Comparison ICT indicators
Venturini (2009)	1980-2004	EU-15, US	Panel DOLS
Vu (2011)	1996-2005	102 countries	GMM
Dimelis & Papaioannou (2011)	1990-2000	US, EU	GMM, panel data
Hwan-Joo & Young Soo (2006)	1992-1996	38 countries	Comparison indicators
Mamaghan (2010)	1965-1995	Developing countries	Comparison indicators
Kauffman & Kumar (2008)	1985-2005	64 countries	Simultaneous equation model
Samoilenko & Ngwenyama, (2011)	1992-1999	Around world	Multivariate regression
Ketteni et al. (2007)	1980-2004	OECD	Nonparametric techniques
Andrianaivo & Kpodar (2011)	1988-2007	African countries	GMM
Specific-country studies	**Period**	**Case Study**	**Method**
Li & Liu (2011)	1985-2006	China	Stochastic frontier
Quirós Romero & Rodríguez Rodríguez (2010)	2000-2005	Spain	Stochastic frontier
Katz (2009)	---	Spain	Theoretical framework
Vourvachaki (2009)	1970-2000	US	Multi-Sector exogenous growth model
Arvaniti & Loukis (2009)	2005	Greece, Switzerland	Firm level production function
Antonopoulos & Sakellaris (2009)	1989-2003	Greece	Neo-classical growth accounting model

Source: Author, 2013

Therefore, in these countries not only is ICT growth sufficient to enhance economic growth but it is a necessary condition. The production function approach is selected because of the fewer assumptions, most specifically, the Cobb-Douglass production functions.

They considered computer software (programming means, agent systems, etc.), hardware (computers, accessories and enhancements), computer and communication services (IT devices, etc.), and wireless communication equipment as a proxy for ICT data. In this respect, the significant and positive effects of mobile telecommunication development on economic growth conducted by Lam et al. (2010) supported the above discussion in high-income countries while Gholami et al. (2006) asserted that developing countries could gain more than industrialised or developed countries through the employment of ICT.

One of the empirical studies on the impact of ICT on growth in the group of countries that were using industry level data was conducted by Dimelis & Papaioannou (2011) who researched over two sub-periods, i.e. 1980-1990 and 1990-2000 for the US and EU industries. Normally, factors related to novelty activity, employment of highly skilled human capital, and Research and Development (R&D) lead to TFP growth. Increased investment in information and communication technology (ICT) capital and growth in human capital contributed substantially to labour productivity growth in market services across all European countries and the US (Inklaar, Timmer, & Van Ark, 2008). In accordance with these results, Cortés and Navarro (2011) believed that countries differ most strongly in the rates of efficiency improvement in the use of inputs and different ICT diffusion. Hence, it was debated as to whether they have also captured different levels of human development (Cortés & Navarro, 2011). A similar story was proven in the newly industrialized Asian countries, such as South Korea, Taiwan, Singapore, Hong Kong, China and India, which have enjoyed a large contribution of ICT in economic growth through four main knowledge and innovation network indices in ICT (Tseng, 2009).

In 15 EU countries and the US, industrial growth has been captured by using log-linear transformation of the Cobb-Douglass production function with respect to TFP, labour, non-ICT and ICT as factors of production. The long run elasticity of ICT is captured by running Panel Dynamic OLS (PDOLS) and panel cointegration analysis (Venturini, 2009). Based on the same results as above, Ketteni et al. (2007) concluded that these are run on a nonlinear approach among ICT capital, human capital, initial income, and economic growth.

In this sense, Vu (2011), Andrianaivo and Kpodar (2011) overcame the endogeneity issues by applying System GMM estimators that exhibited that the growth behaviour of ICT was not similar across the time period at a global level. Therefore, there are distinctions in ICT growth impacts in the ICT-using and ICT-producing sectors over the mentioned period, especially when the ICT effects significantly increased during the 1990s in both the US and EU countries. In this regard, Dimelis and Papaioannou, (2011) compared the long run relationship results between using PMG and GMM estimators. Part of the positive impact of mobile phone penetration on growth for African countries came from superior financial inclusion.

One distinctive study revealed that non-ICT investment has a cumulative causal relationship with economic growth that played a key role in the process of widening the growth gap. ICT investment did not have a strong interdependent relationship with economic growth across 29 countries in the 1990s. This paper introduced a new measurement for the gap in growth using simultaneous equation, three-stage least squares (3SLS) and classifying two groups of countries – frontier group and follower group countries. According to equation (2.4), the growth gap defined the discrepancy of productivity in the two groups (Hwan-Joo, Young, & Jeong, 2009).

(2.4)

$$Gi = Ln\, \frac{PROF}{PROI}$$

Where Gi is the growth gap between two groups, which are frontier group and follower group countries, PRO_F and PRO_I are productivity in frontier group and follower group countries, respectively. Equations (2.5) and (2.6) showed that the output and productivity functions for the two groups of countries have been driven by the average total product:

(2.5)

$Y_i = AiL_i^{\alpha} NICT_i^{\beta} ICT_i^{\gamma}$

(2.6)

$$PRO_{\,i} = \frac{Yi}{Li} = \frac{Ai\ Li\alpha + NICTi\ \beta\ ICTi\gamma}{Li}$$

Where, Y_i is output, L, NICT, ICT as labour non-ICT and ICT inputs, and PRO_i labour productivity. In spite of the main variables like ICT and non-ICT, many explanatory variables like degree of openness to trade, ratio of high-technology exports, and secondary education have been employed, therefore, the unbalanced panel data is suggested in four simultaneous equations (Hwan-Joo & Young, 2006).

Mamaghani (2010), in support of Weber and Kauffman (2011), analysed social, economic and other components that drive global ICT adoption and the organisational, individual, industrial, and economic impacts. This has raised efforts to use ICT to attain a variety of spillover development effects with poverty declining, expansion of health services, extension of educational opportunities and access to government services. In contrast with Mamaghani (2010), Weber and Kauffman (2011), Samoilenko and Ngwenyama (2011) have jointly pointed out that the insignificant impact of the ICT investments on the economics have been due to a shortage of technologically skilled ICT workers who could not adapt themselves to the new circumstance of using ICT.

2.3.2 **Specific-country studies on ICT– economic growth nexus**

In general, researchers have transmitted the effect of ICT on economic growth through three channels. Firstly, ICT is involved as an output or direct contribution to the production of ICT[7] from total value added. Secondly, the ICT capital factor provides economic growth as an input factor in production function. Finally, ICT can increase the economic growth via the ICT-production effects on total factor productivity. This section analyses and summarises the recent studies using a second approach in each individual country and its comparison with non-ICT impacts, which, occasionally, are in conflict across different countries.

A translog production with stochastic frontier model for Chinese and Spanish manufacturing firms estimated the economic growth with respect to human capital and the efficiency of technology for China and Spain (Romero & Rodríguez, 2010). The behaviour of Spanish firms has justified that the e-buying process had a positive impact on firm efficiency, but it became insignificant in the case of e-selling, unlike for the Chinese firms. The empirical results show an improvement in technical progress and its efficiency as the major contributor of the productivity growth but that input growth is the main contributor to GDP growth in the provinces of China (Li & Liu, 2011).

The indirect effects of ICT on US and Spanish economies have been researched by Katz (2009) and Vourvachaki (2009). Multi-sector frameworks that rely on consumer behaviour proved that even the non-ICT-using sector of the US benefited indirectly from ICT, while households' utility increases through using ICT services. However, they proved that if TFP growth and employment establishment were driven partially by the level of ICT investment and telecommunications in the Spanish sector, a reduction in capital expenditure as a result of a certain regulatory framework would have an important effect on the economy.

A comparative study on Greece and Switzerland concerning their production function framework at the firm level revealed that Swiss firms are more mature and efficient than

[7]The approach in this paper is different from Jorgenson et al. (2003) in that they only include ICT investment goods in the production of ICT.

Greek firms in using and creating novelty in ICT as an input (Arvanitis & Loukis, 2009). At the same time, another comparative study between Greece and the US conducted by Antonopoulos and Sakellari (2009), at the industrial level, manifested that ICT investment led to a resurgence of economic resources and TFP growth in Greece. Especially, Arvanitis and Loukis (2009) stated that business services, insurance, finance, wholesale and retail trade industries were the sectors that benefitted most. Unlike the US government and firms, Spain and Greece underrated the benefits of ICT investment, even some of Germany's key sectors had problems in fully exploiting the benefits of ICT. This is because Germany seems to suffer from underinvestment in both IT and software (Welfens, 2008).

In conclusion of this section, we have determined that evidence in multi-country literature studies addressed more comparative studies in the EU and US. Nevertheless, they did not cover the ICT development status of countries to investigate the existence of a relationship between the rank of ICT development and its positive effect on economic growth. The majority of the studies only considered the income level of countries to configure comparative studies and paid little attention to the ICT position of countries. We will follow the multi-country studies in Asia-Pacific and European countries as two different regions. We will cover this gap with our findings in 12 Asia-Pacific and European countries, which are leaders in ICT development in the two regions. We will obtain from our findings whether divergence in economic growth among different countries is due to increasing ICT contribution in the mentioned regions.

2.4 Causality Literature

Although a significant growth in the use of ICT was stated to be an important factor affecting economic growth, its contribution has differed from one country to another and at different developmental stages. Causality tests to assess the causal relationship between economic growth and development of telecommunications were investigated by Hardy (1980); Cronin, Parker, Colleran and Gold (1991); Cronin, Colleran, Herbert and Lewitzky (1993), and Madden and Savage (1998). They found bidirectional causation between infrastructural telecommunication and economic growth in the United States and Central and Eastern European (CEE) countries.

The effect of investment in telecommunication infrastructure on the GDP in 21 OECD countries and emerging industrialized non-OECD countries from 1970 to 1990 was studied by Röller and Waverman (2001). They also reported that the effect is not linear, and that it is higher in OECD countries compared to non-OECD countries. The analysis carried out by Dutta (2001) on 15 industrialized and emerging economies showed that the causality from telecommunication infrastructure to economic activity was stronger compared to the reverse. Datta and Mbarika (2006) found evidence of causality running from information technology development to the growth of service sectors by extending the dataset of Dutta (2001).

A bidirectional association was found between GDP and tele-density for the long and short run in the 12 emerging economies in Asia by Chakraborty and Nandi (2003). Separating the countries into two groups with a high and low level of privatization, the causality was only bidirectional for the countries in the first group. For the low level of privatization group, causality ran from tele-density to GDP in the long run. A positive and significant causal association was found between the regional level of income and ICT infrastructure in Poland, with causality running from the former to the latter (Cieślik & Kaniewska, 2004). In South Korea and the US, a bidirectional association was found between investments in information technology and economic growth (Wolde, 2007).

Shiu and Lam (2007) observed a unidirectional relationship from GDP to telecommunications development in China. However, the reverse causality was observed in the affluent eastern region, not in the low-income central and western provinces. Poor infrastructural telecommunication (i.e. tele-density unable to attain "critical mass") as well as the complementary factor of a low level of economic development (education and training) are some of the reasons for the shortfall in the income effects of the development of telecommunication in the low income western and central provinces. These findings are consistent with previous research that found limitations to the effect of ICT on the growth of the economy or on foreign direct investment in the less developed economies (Dewan and Kraemer, 2000; Jalava and Pohjola, 2002; Gholami, Sang-Yong, & Heshmati, 2006).

Roller and Waverman (1996, 2001), Karner and Onyeji (2007) demonstrated that the impact of ICT on economic development was dependent on the level of growth of ICT. In the advanced economies, as well as areas with high ICT growth, a bidirectional association was found between the development of ICT and economic growth (Lam & Shiu, 2010). In recent research on the General Purpose Technology (GPT) hypothesis, Kretschmer (2012) found strong positive evidence of ICT and TFP growth for United States data; however, it was more difficult to find such evidence in Europe. Therefore, it has been suggested that investigating how spillovers work with ICT may bridge this knowledge gap, particularly since many questions on the subject of possible externalities remain unanswered.

In summary, based on our knowledge from this section, no more attempts have so far been completed to examine the causal relationship between ICT and various determinants of economic growth relying on the Pooled Mean Group (PMG) estimators with the Vector Error Correction Model (VECM) framework on panel data analysis methodologies. Therefore, we are targeting to test the presence and nature of any causal relationship between GDP growth and the contribution of ICT, non-ICT, labour and TFP in the long run and short run by using PMG estimators. Previous research has hypothesized that the rich ICT infrastructure of the receiving host country may increase TFP, which will indirectly lead to economic growth and catch up with the ICT effects on TFP growth through the causality tests. The main contribution of this study is the construction of a comprehensive analysis of causality among the primary key variables of ICT on GDP growth in a multivariate framework in cross-country and cross-industry panel data.

Moreover, this study allows explanation of the differences in the returns of ICT factors separately in ICT-using and ICT-producing sectors across the Asia-Pacific and European countries. The findings of this study will have two aspects of empirical implications. Firstly, it will fill the gap in the literature concerning the causal relationship between ICT and TFP and its impact on economic growth. Secondly, as shown by the causality, it suggests that ICT infrastructure is a significant driver of growth in the long run, henceforth, they should accelerate their ICT deployment.

2.5 Identification of Research Gap

According to the reviewed literature, we have identified the following research gaps that have not been adequately addressed by previous scholars.

1. The review of the assumption of the growth accounting approach has manifested that this framework is less able to fully capture the impact of ICT on economic growth because it does not consider the spillover effects of the impact of ICT. An essential feature of the existence of ICT spillover is whether the ICT capital stock may also boost economic growth through positive spillover effects on TFP if ICT capital is like knowledge capital. Moreover, a major shortcoming traditional growth accounting

suggested by Solow is that it does not cover a significant dimension of the technological changes.

On the other hand, according to the ‘endogenous growth models,’ innovation is a medium for technological spillover effects that permit less developed countries to catch up highly developed countries. Moreover, ICT capital seems to have the characteristics of both forms of capital – traditional forms of capital as a production technology and knowledge capital in its informational nature (Dedrick, Gurbaxani, & Kraemer, 2003). Therefore, we will peruse the ICT impacts from the neo-classical growth model due to ICT as an input of production function and endogenous growth model to deal with ICT spillover effects. Nevertheless, our results are believed to help in taking a modest step towards a deeper perception of the role of ICT in total factor productivity and economic growth.

2. Cross-industry studies on the growth impacts of ICT are still relatively limited, mainly because comparable data sources are quite new. We employ the EU KLEMS database as a unique source in order to be able to compare industrial level findings. Moreover, our study allows explanation of the differences in return of ICT factor separately in ICT-using and ICT-producing sectors across the Asia-Pacific and European countries.

3. Based on the above studies, ICT has a positive effect on productivity growth in EU countries; however, it is less than half of the dimension of the effect found in the US. The present discussions will respond to questions concerning whether aggregate evidence may lead to an apparent productivity paradox in Asia-Pacific and EU countries whereas industry level data presents little evidence for a paradox. To justify this difference, many reasons have been suggested by previous studies, but it is interesting

to investigate whether Asia-Pacific countries, which are leaders in ICT development, followed the EU productivity paradox.

4. The majority of studies on the impact of ICT only consider the income level of countries to configure comparative studies with little attention to the ICT position of countries. From the evidence in the multi-country literature, many studies addressed comparative studies in the EU and US. We will cover these gaps with our findings in 12 Asia-Pacific and European countries that are leaders in ICT development in the two regions.

5. We examine the existence and nature of any causal relationship between GDP growth and contribution of ICT, non-ICT, labour and TFP in the long run and short run. To our knowledge, no more attempts have been made to investigate the causal relationship between ICT and various determinants of economic growth relying on new techniques, such as Pooled Mean Group (PMG) estimators with Vector Error Correction Model (VECM) framework on panel data analysis.

6. The major contribution of this study is the construction of a comprehensive analysis of causality among the primary key variables of ICT on GDP growth in a multivariate framework in cross-country and cross-industry in panel data at the same time. The findings of this study will have theoretical and practical implications. In respect of the theoretical implications, it will fill the gap in the literature concerning the causal relationship between ICT and TFP and its impact on growth. In a practical sense, if our causality test results suggest that ICT infrastructure is an important driver of growth in countries over the long run then they should accelerate their ICT deployment.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Conceptual Framework

In order to organize the new research method and to identify the econometric techniques for future research, we have developed a conceptual research methodology map and economic frameworks (see Figures 3-1, 3-2 and 3-3) that allow us to assess the research findings. The frameworks help to define the key input and output variables and relationships addressed by different estimation methods.

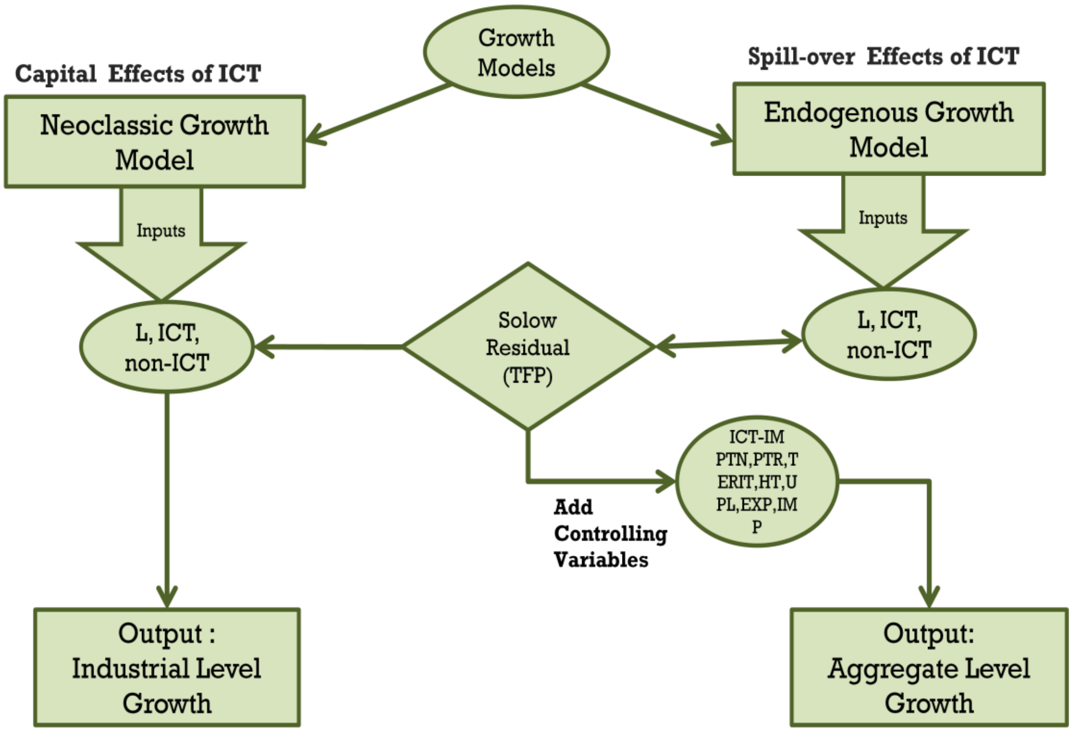

Figure 3-1. Conceptual framework
Source: Deveolped by Romer (1987, 1990) and Solow-Swan (1987)

Moving from up to down in Figure 3-1 the framework identifies the various inputs (labour and ICT and non-ICT capital) that consider the capital and spillover effects of ICT factors for production that influence the production process and enable an assessment of the contribution of inputs to outputs (value added growth in industrial and aggregate level). It further distinguishes between industry and country levels of analysis. Accordingly, neoclassic and endogenous growth models will be employed.

The research methodology in Figure 3-2 outlines the general progress of the research stages.

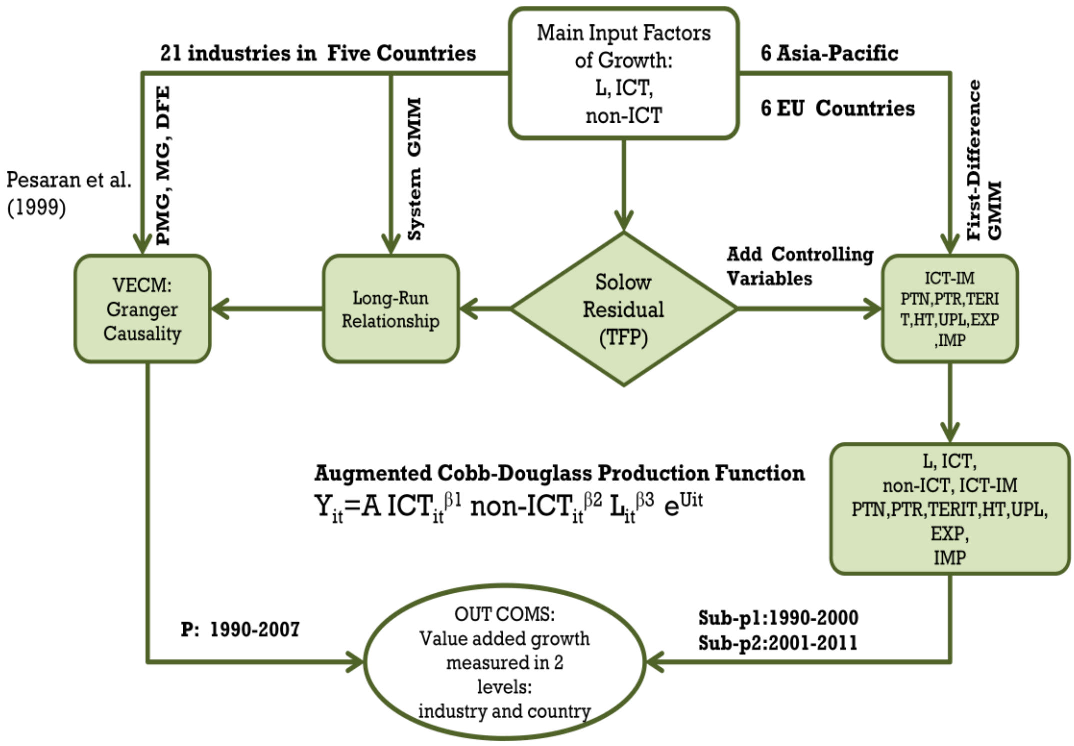

Figure 3-2. Research methodology
Source: Developed byCobb and Douglas, 1947

The econometric framework helps in illustrating how to conduct and develop the error correction model for addressing the causality relationship among variables in the research. We have constructed the main model in detail based on the analysis of Figure 3-3.

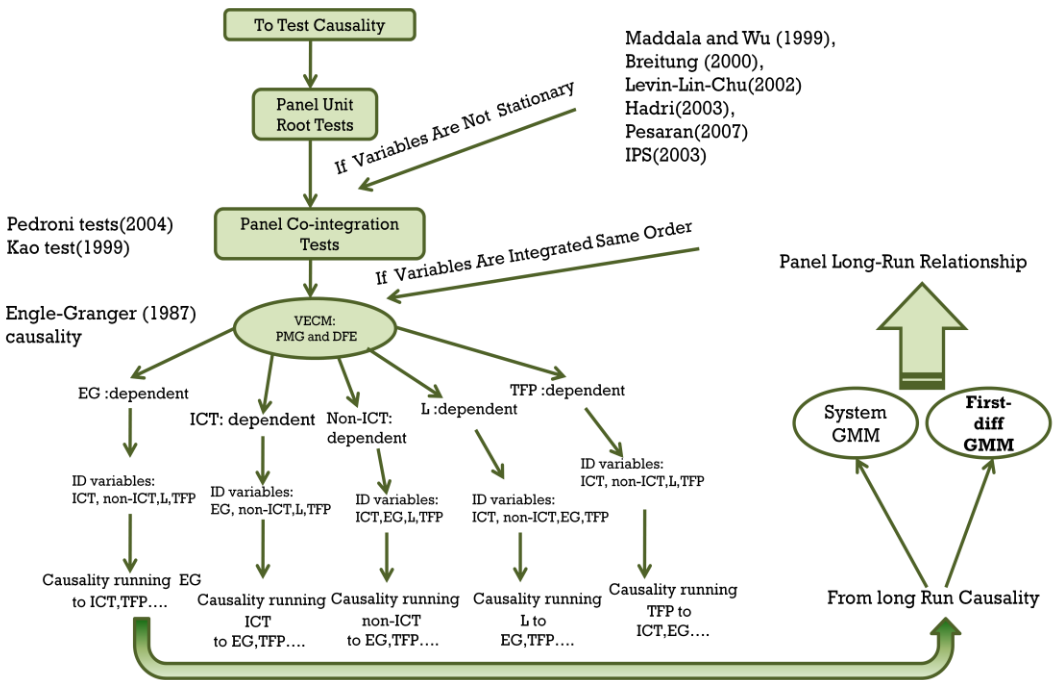

Figure 3-3. Econometric framework
Source: Author Analysis, 2013

3.1.1 **Theoretical background – impact of ICT on TFP and economic growth**

Rapidly emerging technological innovations and growth have evolved as a backbone of current economic growth, resulting in increased attention by economic scholars (Grossman &Helpman, 1991; Aghion & Howitt, 1992). The pace of technology has shifted dramatically from the steam engine to electricity and currently to ICT, referred to as General-purpose Technologies (GPTs), which have played a catalystical role in modern economic growth (David, 1990). These GPTs have been widely recognized due to their critical role in the initial growth stage of the economy, variety of benefits, applicability across multiple sectors and technological complementarities (Bresnahan and Trajtenberg, 1995). The role of GPTs in economic transformation cannot be over-emphasised, as the initial stages of implementation require a major shift of resources from the optimum production of goods and services to the R&D sector for development of new complementary investments. This shift of resources leads to losses in output as well as increased demand for skilled labour and decreased wages for unskilled labour, thereby affecting the overall economy or Total Factor Productivity (TFP). Once the economy has gone through this critical stage and complementary investments have been developed successfully, the application of GPTs is realised across multiple sectors. The national economic cycle enters into a new stage of accelerated TFP and output growth along with a significant rise in the labour wage rate throughout the economy.

David (1990) as well as Bresnahan and Trajtenberg (1995) have acknowledged that as a technology, ICT shares all types of GPTs. As a technology, ICT has deep connections to numerous sectors and a variety of complementary products have been produced (for example communication networks, software products, etc.), which have improved its overall productivity. A few fundamental characteristics attributed to ICT include: (a) conduct goods and services business at a low price, which allows for gains to be obtained through specialisation, economies of scale and recognition of relative benefits; (b) efficient management of information, low transaction costs and facilitation in easing changes in organisation and teaching of skills realised; (c) network impacts imply that with the growth in the number of users the cost of ICTs also rises, and (d) re-allocation of performing inputs in a quicker and more efficient manner. Over time, the developments made in ICT are expected to accelerate economic growth and raise the productivity. The details elaborated upon in the literature point to the fact that in spite of the swift implementation of ICT in the economy by the US, in Europe it has taken decades to realise the latent effects of ICT (Jorgenson, Ho, & Stiroh, 2003).The role of ICT is also a point of divergence among the development agencies, such as the World Bank and International Monetary Fund, as to what is the role of ICT in the development of projects. As some believe that ICT projects have a higher payoff, while others are doubtful of such benefits, like the Asian Productivity Organisation. Nevertheless, consensus between the development specialists and economists is increasing regarding the technological innovation and its diffusion, which can play a vital role in the enhancement of productivity and economic growth (Dedrick, Gurbaxani, & Kraemer, 2003). Early proponents of this outlook included Kendrick (1961), Solow (1987), Abramovitz (1989), Schumpeter and Backhaus (2003). Economists, such as Romer (1990), have emphasised that economic growth and technological change are inextricably related. Thus, diffusion technology creates the possibility for increasing benefits through investment.

3.1.2 Model specification

Firstly, we deployed the Cobb-Douglas production function to investigate the long run and short run relationship between variables. We used two different approaches to estimate the impacts of ICT contribution on economic growth: "the growth accounting approach" and "the production function approach". Under Cobb-Douglas production function, the parameters for both the labour and capital input have to be linearised for estimation in a regression model. This approach is commonly found in the literature of productivity research.

One of the augmented neoclassical models of economic growth is the Cobb-Douglas functional form. The basic Solow model is thus extended to include the contribution of labour capital and ICT, in addition to the contribution of other capital as a non-ICT capital. Furthermore, the production function approach has been broadly employed in previous studies of ICT effects on firm performance (Solow, 1987). The augmented production function requires three resources, i.e. labour employment (L), non-ICT and ICT capital. Hence, we have the following augmented production function:

(3.1)

$$Y_{it}=A\ ICT_{it}^{\beta1}\ non\text{-}ICT_{it}^{\beta2}\ L_{it}^{\beta3}\ e^{Uit}$$

Where Y is value added growth, labour employment (L), non-ICT and ICT capital are contributions to value added growth; A is a constant representing other unobservable factors of production. Finally, β_1, β_2, and β_3 are the elasticities of the production resources. Unobserved variations between cross-sectional overtime have been captured with U_{it} as an error term. For analytical convenience, this function can be transformed into its log-linear form (Gholami, Sang-Yong, & Heshmati, 2006).

(3.2)

$$\ln(Y_{it}) = \alpha + \beta_1 \ln(ICT_{it}) + \beta_2 \ln(\text{non-}ICT_{it}) + \beta_3 \ln(L_{it}) + U_{it}$$

Since this study targets estimation of the growth equation, we have approximated the growth rates employing the log differences, as normally computed in the growth literature:

(3.3)

$$\Delta(\ln Y_{it}) = \alpha + \beta_1 \Delta(\ln ICT_{it}) + \beta_2 \Delta(\ln \text{non-}ICT_{it}) + \beta_3 \Delta(\ln L_{it}) + U_{it}$$

The above formulation in the industrial level part of the research can be further augmented by qualitative information in the form of dummy variables, representing whether an observation comes from an ICT-producing (ICT_prod) or an ICT-using (ICT_use) industry. Justification for the use of such ICT-producing industries has been derived from Jorgenson and Stiroh (2003) who argued that "electrical and optical equipment" has been offered as an industry of ICT manufacture. ICT-using industries was extensively considered while ICT capital will be significant for that industry. To check whether the returns for ICT are greater in the ICT-producing or ICT-using sectors, the interactions of the binary variables with ICT capital (ICT_prod, ICT_use) are classified to test for differences in the ICT returns. At the aggregate level, we have augmented the production function by adding controlling variables to estimate the spillover effects of ICT.

3.1.3 **Solow's residual**

With the productivity of the US economy stagnated even with the increase in computer technology, the infamous ''productivity paradox" was cited by the Nobel laureate economist Robert Solow. He reasoned that ‘‘the computer age is everywhere but in the productivity statistics’’ may be applicable to other developed economies as well (Solow, 1987). Many of the early scholars proved the adverse effects that computers have on productivity since the 1970s and 1980s (Stiroh, 2002b). A number of researchers have tried to explain the post-1970s ‘‘clash of statistics and expectations’’. Evaluation of the productivity paradox provided quite comprehensive descriptions, including wrong measurement of inputs, outputs and their lags in order to learn and adjust accordingly. One of the most commonly documented descriptions regarding the post-1973 slowdown in the productivity was actually a flaw in the methodological frameworks and measurement errors. One more explanation was given that the major payoffs from computer usage is the improvement in quality, customisation and appropriateness and that these were not appropriately measured in certified productivity statistics. A thorough research by a number of scholars discovered a positive influence on output growth by ICT in the 1990s.

Recent studies cited by Brynjolfsson and Saunders (2009) linked productivity growth with ICT. While productivity paradox was effectively negated, contemporary studies have been credited for this revision to conduct a new econometric framework and improve data quality that produced empirical results that are more agreeable. At the level of industry and the firm, some researchers, like Jorgenson and Stiroh (2003), illustrated encouraging proof of returns from ICT capital. It was indicated by Jalava and Pohjola(2002) that still a number of macroeconomic researches still chronicled dissatisfaction in ICT due to the difficulty in identifying the effects on productivity and growth of output. Thus, for more accurate results, better definitions and measurement methods are required, particularly at the aggregate level.

In view of these disagreements, the application of the Solow Residual together with panel data analysis tools at the industrial and aggregate level data is proposed in this study to overcome the methodological inadequacies of prior studies. Our aim is to ascertain empirical evidence concerning the ICT spillover effects to assess previous productivity strategies. Therefore, the application of the Solow Residual suggests the capability of superior measurement of technology related productivity. Tangible outputs were used by most of the earlier studies, for instance, real gross domestic product, national wealth and income. The complete impact of ICT effects on productivity may not be captured by the output measuring process, as its usage impacts are generally considered to be widespread but intangible (Gholami, Sang-Yong, & Heshmati, 2006). Solow's Residual has been calculated in a way that offers more information regarding the changes in technology rather than other measures of productivity, which would make it quite useful in assessing the usefulness of ICT capital. We are assuming that the aggregate production function has a simple Cobb-Douglas functional form.

(3.4)

$$Y = A\, f(K, L) = A\, K^{\alpha} L^{1-\alpha}$$

Where output or GDP is represented by Y, aggregate capital stocks is represented by K, labour factor is represented by L, $A > 0$ is the constant presenting intangible factors of production, which measures the available technology's productivity, and elasticity of the production resources is presented by share parameter $0 < \alpha < 1$. Total factor productivity (TFP) is often referred to as Solow's Residual and it is explained by economists as being part of the country's unexplained economic productivity, which is mainly credited to technology. TFP as a Solow's Residual can be derived by utilising the equation 5 production function, as follows:

(3.5)

$$A = Y / (K^{\alpha} L^{1-\alpha})$$

The value of α has been estimated by several researchers regarding growth accounting either econometrically or by employing national account data for national and industrial level data (Gholami, 2006).

3.1.4 Endogenous growth theory

Any enhancing of the output not attributed to an increase in input is called total factor productivity. TFP growth is assumed to stand for exogenous (disembodied) technological change in the neoclassical model. Beyond exogenous technological transform, additionally, it contains the contribution of further indeterminate inputs, dissimilarity from constant returns to scale and also perfect competition and specification errors. TFP progress in the growth accounting approach is a residual of output growth that may not be described by the conventional input components as appropriate cause for economic growth.

As mentioned previously in the literature concerning growth components like investment and savings (in classical models) and technical progress (in neo-classical models), these have been documented as the sources of economic growth. However, in the endogenous growth model, R&D, externalities, and labour capital accumulation have been accredited as the sources of economic growth. Recent concerns in the endogenous theories of economic growth have concentrated on the character and role of knowledge in the growth procedure since knowledge has a particular property in that, once produced, it can spillover simply at zero marginal cost leading to accelerated returns and output growth (Romer 1986, 1990; Grossman & Helpman, 1991). In other words, various resources of long run growth have been considered in the endogenous growth theory, in which each of them involves an externality connected with some components, such as education and technology progress (R&D) through knowledge improvements.

Therefore, we have conducted our model with respect to the endogenous growth model notwithstanding that the conventional factors of growth model added some controlling variables to the aggregate level. These controlling variables include education, knowledge and trade components, which influence output growth through the spillover effects of ICT (Gholami, 2006).

3.1.5 **Modelling the ICT Spillovers under the Impacts on TFP**

The spillover effects of ICT are externalities of economic processes that affect those that are not directly involved. This means that the externality of ICT follows from a primary ICT contribution, and may be disseminated in time or place from the event that caused the primary effect. In addition, the spillover effect of ICT cannot be measured by a single variable. At the industrial level, besides exogenous technological change, TFP also covers the contribution of other unspecified inputs, such as ICT contribution.

It remains an open debate as to precisely which part of the effects of ICT spillover is indirectly channelled through TFP growth, and which part is directly accounted due to the additional variables. Our research handles ICT spillover effects via TFP growth at the industrial level and looks at different angles of ICT spillover effects through additional variables, such as the components of education, trade and innovation. Therefore, this thesis has modelled the spillover effects of ICT via two channels: first, modelling the ICT spillover effects via TFP impact, and, second, measurement of the ICT spillover effects independently from TFP. According to the first channel, TFP growth in the growth accounting method is a residual of output growth that cannot be accounted for by the traditional input factors.

Modelling of R&D spillovers is one of the well-known practices in measuring spillover effects. Similar to the R&D spillovers practice, we obtain empirical results of industries based on a linear approximation that associates value added growth to the spillover effect of ICT growth through TFP contribution growth. To address this concept, from the initial estimation of causality results, if there is a causal relationship running from ICT to TFP contribution we can conclude that TFP growth affects economic growth as a spillover effect of ICT. To set up the linear approximation, we first have to establish TFP using the Cobb-Douglas production function, which is pervasive in the productivity research literature. This approach has also been extensively used in earlier researches of ICT effects on aggregate output performance (Pilat, 2004; Gretton, Gali, & Parham, 2004; Elsading 2008; Jalava, 2003; Jalava & Pohjola, 2002, 2007; Hwan-Joo and Young Soo, 2006; Dahl et al., 2011).

Therefore, we assume a Cobb-Douglas aggregate production function, as follows:

(3.6)

$$Y = A\ f\ (K_{ICT}, K_{non\text{-}ICT}, L) = A.\ K^{\alpha}_{ICT}.\ K^{\beta}_{non\text{-}ICT}\ .\ L^{\gamma}$$

'*A'* has been taken to be just a residual or 'unexplained' part of a country's economic output growth. Nevertheless, under the endogenous growth theory conventional concept was renamed from '*A'* to 'TFP', which, according to Quah (2001), now turns out to be the engine of economic growth. Using the production function from equation (3.1), TFP can be derived as:

(3.7)

$$Y/K^{\alpha}_{ICT}.\ K^{\beta}_{non\text{-}ICT}\ .\ L^{\gamma} = A.\ K^{\alpha-1}_{ICT}.\ K^{\beta-1}_{non\text{-}ICT}\ .\ L^{\gamma-1}$$

(3.8)

$$TFP = A.\ K^{\alpha-1}_{ICT}.\ K^{\beta-1}_{non\text{-}ICT}\ .\ L^{\gamma-1}$$

(3.9)

$$Ln\ TFP = a_0 + (\alpha-1)Ln\ K_{ICT} + (\beta-1)\ Ln\ K_{non\text{-}ICT} + (\gamma-1)\ Ln\ L$$

(3.10)

$$Ln\ TFP = a_0 + (\alpha)\ Ln\ K_{ICT} + (\beta)\ Ln\ K_{non\text{-}ICT} + (\gamma)\ Ln\ L - (Ln\ K_{ICT} + Ln\ K_{non\text{-}ICT} + Ln\ L)$$

(3.11)

$$Ln\ TFP = Ln\ Y - (Ln\ K_{ICT} + Ln\ K_{non\text{-}ICT} + Ln\ L)$$

Following Coe and Helpman (1995), the basic TFP equation used to assess the ICT spillover effect is:

(3.12)

$$Ln\ TFP_{it} = Ln\ Y_{it} - (Ln\ K_{ICT} + Ln\ K_{non\text{-}ICT} + Ln\ L)_{it} + \varepsilon_{it}$$

We can rewrite the equation (3.9):

(3.13)

$$tfp_{it} = a_0 + (\alpha-1)\ ict_{it} + (\beta-1)\ non\text{-}ict_{it} + (\gamma-1)\ l_{it}$$

(3.14)

$$y_{it} = a_0 + \alpha\ ict_{it} + \beta non\text{-}ict_{it} + \gamma\ l_{it} + \delta\ tfp_{it}$$

In the preceding model equations, we have only counted Y (value added growth), ICT, non-ICT and labour capital contribution, as right hand side factors of total factor productivity; however, we should be aware that these are generally not the only resources and determinants for this kind of productivity growth.

3.1.6 **Measurement of ICT Spillover Effects Independent of TFP**

Through the second channel, ICT would form a new ‘wave’ of innovation, education and trade, which has an impact on value added growth. This has been observed in earlier waves, such as the introduction of steam power or electricity. Indeed, the main benefits of ICT are related to their networking and learning abilities (information management, data exchange, firm connectivity, diffusion of best practices, etc.), and countries need to re-organize their businesses to benefit fully from the technological advancement of companies. ICT is subject to strong externalities or spillover effects, which allows for diffusion of ICT innovation across national boundaries independently of TFP growth.

One of the modes of diffusion of innovation is through traded products with innovative technology. The concept of externalities, neighbourhood effects or knowledge spillovers was first described in 1890 by Alfred Marshall. Marshall (1920) observed that innovative knowledge benefits the inventor for a rather short time: “the most important improvements in method seldom remain secret for long after they have passed from the experimental stage”.

The importance of trade as a vehicle for international transmission of knowledge contributing to economic growth was discussed by Coe and Helpman (1995), and followed by a number of studies (Coe & Hoffmaister 1999; MacGarvie 2005). Trade influences a country’s growth rate by impacting upon the level of these activities and by facilitating the transmission of technology across borders. Much research has been done in recent years to assess the importance of R&D in influencing output growth. The endogenous growth theory establishes the view that R&D investment directly contributes to knowledge accumulation (Romer, 1990; Grossman & Helpman, 1991; Aghion & Howitt, 1997). Value added growth is affected by the spillovers of ICT stocks, which accumulate as an outcome of R&D activity, such as patent applications and high technology exports or as a result of internationally traded ICT containing embodied technological advances.

Furthermore, the endogenous growth theory considers various sources of long run growth, each of which involves an externality associated with some activity, such as education like school enrolment through knowledge (R&D) activities. We expect to discover certain group patterns of reaping benefits from the ICT spillover effects by incorporating the group of variables.

Hence, our equation is further modified by variables, such as patent application, school enrolment, high technology export and trade components. We also control for other potential growth drivers of the spillover effects of ICT like unemployment rate and ICT imports with augmenting equations (3.15) and (3.16) as follows:

(3.15)

$$tfp_{it}= a_0+ (\alpha-1)\ ict_{\ it}+(\beta-1)\ non\text{-}ict_{\ it}+(\gamma-1)\ l_{\ it}+ \theta_1 ictim_{\ it}+\theta_2\ ptn_{\ it}+ \theta_3\ ptr_{\ it}+ \theta_4\ terit_{\ it}+ \theta_5\ ht_{\ it}+ \theta_6\ upl_{\ it}+ \theta_7 exp_{\ it}+ \theta_8\ imp_{\ it}$$

(3.16)

$$y_{it} = a_0+ \alpha\ ict_{\ it}+\beta non\text{-}ict_{\ it}+\gamma\ l_{\ it}+\delta\ tfp_{it}+ \theta_1 ictim_{\ it}+\theta_2\ ptn_{\ it}+ \theta_3\ ptr_{\ it}+ \theta_4\ terit_{\ it}+ \theta_5\ ht_{\ it}+ \theta_6\ upl_{\ it}+ \theta_7\ exp_{\ it}+ \theta_8\ imp_{\ it}$$

Where ictim is “ICT Goods Imports (% total goods imports)”, ptn is “Patent Applications, Non-residents”, ptr is “Patent Applications, Residents”, terit is “School Enrolment, Tertiary (% gross)”, ht is “High-Technology Exports (% of manufactured exports)”, upl is “Unemployment, Total (% of total labour force)”, exp is “Exports of Goods and Services (% of GDP)”, imp is “Imports of Goods and Services (% of GDP)”. However, we will consider the significance of newly added variables, such as θ2, θ3, θ4, θ5, θ7, and θ8 for controlling the spillover effects of ICT in the long run estimation of equation (3.16), which is independent of the TFP growth effects.

3.2 Econometric Methodology

3.2.1 **Panel multivariate causality model**

Generally, in bivariate models, to test Granger-causality, the restricted form and unrestricted form are specified for variables. If two variables have a unit root in level but they become stationary after first differencing, the standard form of the Granger-causality test can be applied, as follows:

(3.17)

$$\Delta Y_t = \alpha_{11} + \sum_{i=1}^{L11} \beta_{11i} \Delta Y_{t-i} + U_{11t}$$

(3.18)

$$\Delta Y_t = \alpha_{12} + \sum_{i=1}^{L11} \beta_{11i} \Delta Y_{t-i} + \sum_{j=1}^{L12} \beta_{12j} \Delta X_{t-j} + U_{12t}$$

(3.19)

$$\Delta X_t = \alpha_{21} + \sum_{i=1}^{L21} \beta_{21i} \Delta X_{t-i} + U_{21t}$$

(3.20)

$$\Delta X_t = \alpha_{22} + \sum_{i=1}^{L21} \beta_{21i} \Delta X_{t-i} + \sum_{j=1}^{L22} \beta_{22j} \Delta Y_{t-j} + U_{22t}$$

Equations (3.18) and (3.20) are in unrestricted forms while equations (3.17) and (3.19) are in restricted forms. However, equations (3.17) and (3.18) are illustrated pairs to distinguish whether the coefficients of the past lags of X can be zero as a whole. Similarly, equations (3.19) and (3.20) illustrate another pair to identify whether the coefficient of the past lags of Y can be zero as a whole. If the estimated coefficient on lagged values of X in equation (3.18) are significant, it indicates that some of the variation of Y is explained by the other variables like X and not the lagged values of Y itself. This implies that X Granger-causes Y; therefore, the F-test is applied to examine whether the coefficients of the lagged values are zero.

Similar analysis is achievable for testing whether Y Granger-causes X. If two variables also have a unit root after first differencing, but they would become stationary after second differencing, to examine for Granger-causality between two variables, equations

(3.17)-(3.20) must be estimated with the second differenced data. The main reason for applying equations (3.17)-(3.20) is for the testing the Granger-causality between two variables; stationary series must be used (Yoo, 2006). In a specific condition, if X and Y are each non-stationary and cointegrated, then any standard Granger-causal implication will be invalid and the best way to apply the causality test will be to adopt the structure of an error-correction model (ECM) in this condition (Engle & Granger, 1987). Thus, in order to capture comprehensive results we have also extended modified bivariate causality ECM in equations (3.18) and (3.20) to multivariate causality ECM in (3.22)-(3.26) below.

The empirical research of the dynamic causal association among economic growth, contribution of ICT, non-ICT, labour, and TFP, by applying recent econometric techniques involves the following three phases. In the initial step, if each panel variable is involved, a unit root is checked. In the case where the variables include a unit root, the second phase is to examine whether there is certainly a long run cointegration relationship between the panel variables. Once a long run relationship between the variables becomes apparent, the final step is to estimate the panel vector error correction model using the new panel dynamic procedures to establish the Granger causal relationship between the variables (Sharif Hossain, 2012).

The cointegration relationship tests are only adequate for indicating the causal relationship and do not specify the way of causality among the variables. Consequently, it is widespread practice to examine for the causal relationship among variables using the Engle-Granger test procedure. In the presence of a cointegration relationship, applying the Engle-Granger (1987) causality test in the first differenced level of variables by vector auto-regression (VAR) structure will yield misleading results. Therefore, the insertion of an additional variable, such as the error correction term (ECT) to the VAR system would aid in capturing the long run relationship (O'Mahony

& Vecchi, 2005). The augmented error correction representation to test the multivariate Granger causality is formulated in the matrixes given below.

(3.21)

$$\begin{bmatrix} Ln\ EGit \\ LnICTit \\ LnNICTit \\ LnLit \\ LnTFPit \end{bmatrix} = \begin{bmatrix} C1 \\ C2 \\ C3 \\ C4 \\ C5 \end{bmatrix} + \sum_{i=o}^{p} \begin{bmatrix} \beta 11,k & \beta 12,k & \beta 13,k & \beta 14,k & \beta 15,k \\ \beta 21,k & \beta 22,k & \beta 23,k & \beta 24,k & \beta 25,k \\ \beta 31,k & \beta 32,k & \beta 33,k & \beta 34,k & \beta 35,k \\ \beta 41,k & \beta 42,k & \beta 43,k & \beta 44,k & \beta 45,k \\ \beta 51,k & \beta 52,k & \beta 53,k & \beta 54,k & \beta 55,k \end{bmatrix} . \begin{bmatrix} Ln\ EGit-k \\ LnICTit-k \\ LnNICTit-k \\ Ln\ \ Lit-k \\ LnTFPit-k \end{bmatrix} +$$

$$\begin{bmatrix} \lambda 1 \\ \lambda 2 \\ \lambda 3 \\ \lambda 4 \\ \lambda 5 \end{bmatrix} \text{ECM}_{\text{it-1}} + \begin{bmatrix} \varepsilon 1it \\ \varepsilon 2it \\ \varepsilon 3it \\ \varepsilon 4it \\ \varepsilon 5it \end{bmatrix}$$

The C's, β's and λ's are the parameters to be estimated. Δ stands for first difference, $\text{ECM}_{\text{it-1}}$ represents the one period lagged error-term derived from the cointegration vector and the ε's are serially independent with finite covariance and matrix, and zero mean. The above matrixes employ a vector error correction model (VECM) and all the variables are assumed to be endogenous variables. Therefore, the above VECM could be converted in the following equation in order to test Granger Causality.

(3.22)

$$\Delta \ln EG_{it} = C_1 + \sum_{i=1}^{k} \beta_{i1} \Delta \ln EG_{it-k} + \sum_{i=0}^{k} \beta_{i2} \Delta \ln L_{it-k} + \sum_{i=0}^{k} \beta_{i3} \Delta \ln ICT_{it-k} + \sum_{i=0}^{k} \beta_{i4} \Delta \ln nonICT_{it-k} + \sum_{i=0}^{k} \beta_{i5} \Delta \ln TFP_{it-k} + \lambda 1ECT_{it-1} + \varepsilon_{it}$$

(3.23)

$$\Delta \ln L_{it} = C_2 + \sum_{i=0}^{k} \beta_{i1} \Delta \ln EG_{it-k} + \sum_{i=1}^{k} \beta_{i2} \Delta \ln L_{it-k} + \sum_{i=0}^{k} \beta_{i3} \Delta \ln ICT_{it-k} + \sum_{i=0}^{k} \beta_{i4} \Delta \ln nonICT_{it-k} + \sum_{i=0}^{k} \beta_{i5} \Delta \ln TFP_{it-k} + \lambda 2ECT_{it-1} + \varepsilon_{it}$$

(3.24)

$$\Delta \ln ICT_{it} = C_3 + \sum_{i=1}^{k} \beta_{i1} \Delta \ln EG_{it-k} + \sum_{i=0}^{k} \beta_{i2} \Delta \ln L_{it-k} + \sum_{i=1}^{k} \beta_{i3} \Delta \ln ICT_{it-k} + \sum_{i=0}^{k} \beta_{i4} \Delta \ln nonICT_{it-k} + \sum_{i=0}^{k} \beta_{i5} \Delta \ln TFP_{it-k} + \lambda 3ECT_{it-1} + \varepsilon_{it}$$

(3.25)

$$\Delta \ln nonICT_{it} = C_4 + \sum_{i=1}^{k} \beta_{i1} \Delta \ln EG_{it-k} + \sum_{i=0}^{k} \beta_{i2} \Delta \ln L_{it-k} + \sum_{i=0}^{k} \beta_{i3} \Delta \ln ICT_{it-k} + \sum_{i=1}^{k} \beta_{i4} \Delta \ln nonICT_{it-k} + \sum_{i=0}^{k} \beta_{i5} \Delta \ln TFP_{it-k} + \lambda 4ECT_{it-1} + \varepsilon_{it}$$

(3.26)

$$\Delta \ln TFP_{it} = C_5 + \sum_{i=1}^{k} \beta_{i1} \Delta \ln EG_{it-k} + \sum_{i=0}^{k} \beta_{i2} \Delta \ln L_{it-k} + \sum_{i=0}^{k} \beta_{i3} \Delta \ln ICT_{it-k} + \sum_{i=0}^{k} \beta_{i4} \Delta \ln nonICT_{it-k} + \sum_{i=1}^{k} \beta_{i5} \Delta \ln TFP_{it-k} + \lambda 5ECT_{it-1} + \varepsilon_{it}$$

Where i = 0, 2,……..,k; t = p+1, p+2, p+3,……….,T

The F test will be applied here to test the direction of any causal relationship among the variables. The hypothesis for short run causality that would have been examined is:

H_{01}: $\beta 11, k = \cdots \beta 15, k$=0, meaning ICT, non-ICT, L and TFP do not Granger cause EG

H_{02}: $\beta 21, k = \cdots \beta 25, k$=0, meaning ICT, non-ICT, EG and TFP do not Granger cause L

H_{03}: $\beta 31, k = \cdots \beta 35, k$=0, meaning EG, non-ICT, L and TFP do not Granger cause ICT

H_{04}: $\beta 41, k = \cdots \beta 45, k$=0, meaning ICT, EG, L and TFP do not Granger cause non-ICT

H_{05}: $\beta 51, k = \cdots \beta 55, k$=0, meaning ICT, non-ICT, L and EG do not Granger cause TFP

While for long run causality, we will be testing the following hypotheses:

H_{01}: $\lambda 1$=0, meaning ICT, non-ICT, L and TFP do not Granger cause EG

H_{02}: $\lambda 2$ =0, meaning ICT, non-ICT, EG and TFP do not Granger cause L

H_{03}: $\lambda 3$ =0, meaning EG, non-ICT, L and TFP do not Granger cause ICT

H_{04}: $\lambda 4$ =0, meaning ICT, EG, L and TFP do not Granger cause non-ICT

H_{05}: $\lambda 5$ =0, meaning ICT, non-ICT, L and EG do not Granger cause TFP

Moreover, the coefficients in the ECT display how quickly diversions from the long run equilibrium are removed.

3.2.2 **Panel unit root tests**

Following a line of investigation in the unit root for panel data has recently attracted a lot of interest. Testing for the stationary manner of time series is now usually applied by many scholars and has become an integral section of the econometric analysis. The easier access to panel data for researchers is the cause of panel unit root tests becoming ever more pervasive. It is currently established that previous unit root tests, such as Dickey-Fuller (DF), Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests, are powerless in determining the stationary of variables so the use of the panel unit root test approach is one way of raising the power of tests. The differences in power between previous stationary tests and panel unit root tests have been demonstrated by many econometrists, such as Breitung (2000), Maddala and Wu (1999), Levin, Lin, and Chu (2002), Hadri, Guermat, and Whittaker (Hadri, 2000; 2003), Pesaran (2003), Im, Pesaran, and Shin (2003). As none of the panel unit root tests is free from certain statistical inadequacies in terms of power and size properties, it enhances our research to carry out a number of panel unit root tests to provide overpowering evidence to determine the order of integration of the panel variables. In this study, we employ panel unit root tests, which can be arranged in groups by heterogeneous or homogenous, and cross-section dependence or independence, which were proposed by Maddala and Wu (1999), Breitung (2000), Levin-Lin-Chu (2002), Hadri (2000), Pesaran (2003), Im, Pesaran, and Shin (2003).

Table 3-1. Panel unit root test classification

Cross-section Independence	**Cross-section Dependence**
Homogenous Unit Root Tests	**Heterogeneous Unit Root Tests**
Hadri (2000) HC Z-Statics Levin-Lin-Chu(2002) t-statistics Breitung (2000) t-statistics	Maddala & Wu (1999) ADF-Fisher Chi Square Maddala & Wu (1999) PP-Fisher Chi Square Pesaran (2003)
Heterogeneous Unit Root Tests	
Im, Pesaran and Shin (2003) W-statistics	

Note: All panel unit root tests are testing the null hypothesis of non-stationary except the Hadri (2000) test that is testing stationary.
All panel unit root tests are defined by the Bartlett kernel and Newey-West (1994) bandwidth, except that Hadri (2000) is defined by the quadratic spectral kernel and Andrews (1991) bandwidth selection.
Hadri (2000) assumes that the unit root test uses heteroscedasticity consistent.
The optimal number of lags is chosen by Akaike Information Criterion (AIC).
The probabilities for the Fisher tests are computed using an asymptotic chi-square distribution.
All other tests assume asymptotic normality.

Source: Author, 2013

Levin-Lin-Chu (2002) indicated that the power of unit root tests would be enhanced by developing information for cross-sectionals. They offered a panel-based ADF test that limits parameters γ_i by considering them identical during cross-sectional regions as follows:

(3.27)

$$\Delta y_{it} = \alpha_i + \gamma_i y_{it-1} + \sum_{j=1}^{k} \alpha_j \Delta y_{it-j} + e_{it}$$

Where t =1,. . ., T time periods and i =1, ...N members of cross-sectionals in panel. Levin-Lin-Chu (2002) tested the null hypothesis of $\gamma_i = \gamma = 0$ for all i, against the alternate of $\gamma_1 = \gamma_2 = ... = \gamma < 0$ for all i, with the test based on statistics $t\gamma = \hat{\gamma}/s.e.(\hat{\gamma})$. One disadvantage is that γ is limited by creature identical across regions under the null and alternative hypotheses (Lee, 2005).

The Im, Pesaran, and Shin (2003) test made free the assumptions of the Levin-Lin-Chu (2002) test by allowing β to differ across units under the alternative hypothesis, which allows for heterogeneity in the autoregressive coefficients for all panel members. The t-bar test proposed by Im, Pesaran and Shin (2003) assumes that all cross-sections also congregate in the direction of the equilibrium value at dissimilar speeds under the alternative hypothesis as well. Two phases were proposed in constructing the t-bar test statistic. Firstly, the mean of the individual Augmented Dickey-Fuller (ADF) t-statistics have been calculated for each of the cross-sectionals (N) in the sample. Secondly, calculating the standardized t-bar statistic has been done as follows:

(3.28)

$$\text{t-bar} = \frac{\sqrt{N}}{\sqrt{vt}} (t_\alpha - k_t)$$

Where t_α is the mean of the particular ADF t-statistics for each of the cross-sectionals with or without a trend, N is the dimensions of the panel k_t and ν_t, respectively, approximations of the mean and variance of each one $t_{\alpha i}$. Im, Pesaran , and Shin (2003) presented Monte Carlo simulations of k_t and ν_t and accurately tabulated critical values for a range of combinations of N and T. A challenge with the t-bar test is the fact that the test is simply not applicable if there is cross-sectional dependency in the disturbances. Nevertheless, Im, Pesaran, and Shin (2003) advised that in the presence of cross-sectional dependency, the data might be modified by demeaning that the standardized demeaned t-bar statistic congregates to the standard normal in the control.

An optional technique to the panel unit root tests is to apply Fisher's (1925) method to obtain results that merge the p-values of individual unit root tests. Subsequent to the Fisher (1925) test, Maddala and Wu (1999), based on the Fisher (1925) test, provided a non-parametric test statistic. This test primarily synthesizes the p-values of a particular unit root test in any residual cross-sectional unit. The test is a sort of non-parametric test and includes a chi-square distribution with 2N levels of freedom, whereas N is the number of countries or cross-sectional units. The following test statistic tends to be obtained by applying the additive property of the chi-squared variable:

(3.29)

$$\lambda = -2 \sum_{i=1}^{N} log_{e} \pi_{i}$$

Where, π_i is the p-value of the test statistic for unit i. One of the advantages of the Maddala and Wu (1999) test on the Im, Pesaran and Shin (2003) test is that it is independent on different lag lengths in the individual ADF regressions. Maddala and Wu (1999) carried out Monte Carlo simulations presenting which is better to that proposed by Im, Pesaran and Shin (2003).

Another panel unit root test proposed by Breitung (2000) is a recent large-scale Monte Carlo simulation presented by Narayan and Smyth (2009). They found that the Breitung (2000) panel unit root test commonly had the maximum power and least size bend of every test that are called first generation panel unit root tests. The following equation is the Breitung (2000) panel unit root test:

(3.30)

$$Y_{it} = \alpha_{it} + \sum_{k=1}^{p+1} \beta_{ik} X_{i,t-k} + \varepsilon_t$$

The Breitung (2000) test employs equation (30) to test statistics under the following null hypothesis that the process has a unit root: H_0: $\sum_{k=1}^{p+1} \beta_{ik\ -1} = 0$. The alternative hypothesis assumes that the panel series does not have a unit root; that is, $\sum_{k=1}^{p+1} \beta_{ik\ -1} < 0$ for all i. The following transformed vectors to extract the test statistic are used by Breitung (2000):

(3.31)

$$Y^*_i = A\ Y_i = [y^*_{i1}, y^*_{i2,\ldots}, y^*_{iT}]'$$

(3.32)

$$X^*_i = A\ X_i = [x^*_{i1}, x^*_{i2}, \ldots, x^*_{iT}]'$$

These lead to the following test statistic:

(3.33)

$$\lambda_\beta = \frac{\sum_{i=1}^{N} \sigma\ 1-2\ Y'i{*}X'i{*}}{\sqrt{\sum_{i=1}^{N} \sigma\ 1-2X'i{*}A'AXi{*}}}$$

This is expected to have a normal standard distribution (Mishra, Smyth, & Sharma, 2009). The results of the panel unit root tests are reported in chapter 4. The test statistics for the majority of level variables are statistically insignificant with some exceptions that we will deal with in detail in chapter 4. Considered an entity, the level outcomes endorse that all the variables are panel non-stationary; consequently, we employ the panel unit root tests to the first difference of variables.

However, Hadri (2000) proposed that the null hypothesis has to be reversed to be the stationary hypothesis to establish a more robust test. The Lagrange Multiplier (LM) statistic for Hadri’s (2000) test could be written as:

(3.34)

$$L\hat{}M = \frac{1}{N} \sum_{i=1}^{N} \left(\frac{\frac{1}{T2} \sum_{i=1}^{T} S2it}{\hat{\sigma}2} \right), Sit = \sum_{j=1}^{t} \hat{\varepsilon} ij,$$

where $\hat{\sigma}^2$ is in line with Newey and West's (1987) estimation of the long run variance of disturbance terms (Lee, 2005).

Several panel unit root tests are offered. In our empirical analysis, we will use a recent panel unit root test improved by Pesaran (2003), which has accounted for cross-sectional dependence. Based on the applied economics literature, given that this test is comparatively new and less used it has provided some additional information concerning this test. Pesaran (2003) built a panel unit root test by improving the augmented Dickey-Fuller (ADF) regression with cross-sectional means of first differences and lagged levels of the individual series. This test is named as the cross-sectional augmented ADF (CADF) test, which assumes that all series are non-stationary under the null hypothesis. The following regression represents the CADF test here.

(3.35)

$$\Delta y_{it} = \alpha_i + \beta_i y_{it-1} + \eta_i \bar{y}_t + k_i \Delta \bar{y}_t + \varepsilon_{it}$$

Where, $\bar{y}_t$ is the average of the variable y_t. Amount of null hypothesis to test the unit root is H_0: $\beta_i = 0$ for all i. Against the probable alternative hypothesis H_1: $\beta_i < 0$, $i = 1,2,\ldots,N_1$, $\beta_i = 0$, $i = N_1+1, N_1+2,\ldots,N$

To examine the null hypothesis, the t-test has been employed. The distribution is not normal/abnormal, whereas critical values are produced by Pesaran[8] (2003) as well as Narayan, Narayan, and Popp (2010).

3.2.3 **Panel cointegration tests**

Since we extracted Solow's Residual as a measure of productivity, we need to examine the causal relationship between the value added growth (Y in the equations) and ICT, Solow's Residual (A in the equations), labour and non-ICT. To analyse the long run relationship between variables, we employed the vector error correction model (VECM) and system generalized moment of method (GMM) in panel data analysis. Over time

[8]More technical details can be found in Pesaran M.H. "A simple panel unit root test in the presence of cross-section dependence". J Appl Econom 2007; 22:265–312.

series studies, two variables are supposed to have a long run relationship whether they are cointegrated. We are able to estimate the variables in equation (2) to be cointegrated, if the order of integration of the left hand side variable (economic growth) would be equal to or larger than the highest order of integration of the right hand side variables (K, L, ICT, non-ICT and TFP). Otherwise, even without cointegration tests, they are clearly not cointegrated.

Before the cointegration test, we carried out the panel unit root tests to determine the order of integration of the variables. This test was helpful to identify stationary variables for the Granger causality test. According to the results of the Hausman and F-tests, we developed the vector error correction model (VECM) by employing the pooled mean group (PMG), mean group (MG), and dynamic fixed effect (DFE) estimators to identify the causal relationship among variables. The concept of cointegration was first made popular by Granger (1981) and improved further by Engle and Granger (1987); Johansen (1988, 1991) and Phillips and Ouliaris (1990), among others. The fundamental concept is that if two or more time series variables are individually integrated of order *n*, then there is a possibility of at least one linear combination to be integrated of a lower order than *n*.

Therefore, such a relationship between these variables concludes cointegration. Cointegrated variables display a strong stable-state relationship in the long run, having general trends and co-movements similar to panel unit root tests. By extension of the time series cointegration tests to panel cointegration, two groups of tests have been proposed: the first group of tests considers cointegration as the null hypothesis (McCoskey & Kao, 1998; Westerlund & Edgerton, 2007) whereas the other group of tests considers no cointegration as the null hypothesis (Pedroni, 1999; Kao, Chiang & Chen, 1999; Groen & Kleibergen, 2003; Larsson, Lyhagen & Löthgren, 2008).

Once the presence of a panel unit root has been recognized, the concern arises as to whether there is a long run equilibrium relationship among the regressors. In the current research, we have used two methods of panel cointegration test. The first set of tests is proposed by Pedroni (2004). The second set is from Kao (1999), which is the generalized Augmented Dickey-Fuller (ADF) tests in the panel data framework. These two tests have shown no cointegration possibility under the null hypothesis while employing the residuals comprising of a panel regression to make the test statistics and establish the distributions.

Pedroni's cointegration test methodology like the Im, Pesaran and Shin (2003) test, is a heterogeneous panel cointegration test that was improved by Pedroni (1999, 2004) allowing cross-sectional interdependence with different individual effects. The following equation presents the empirical model of Pedroni's cointegration test.

(3.35)

$$Y_{it} = \eta_i + \delta_{it} + \sum_{i=0}^{n} \beta_i X_{it} + \varepsilon_{it}$$

Where i=0,1,2,…,N for each country or industry in the panel and t=0,1,2,…..,T denotes the time period; Y, and X are dependent and independent variables. η_i and δ_i are country or industry and time fixed effects, respectively (Uysal, 2010). A deviation from the long run relationship is accounted for by ε_{it}, which is estimated by residuals. The estimated residuals are structured as follows:

(3.36)

$$\hat{\varepsilon}_{it} = \hat{\rho}_i \hat{\varepsilon}_{it-1} + \hat{u}_{it}$$

Seven different statistics to test the panel data long run relationship were proposed by Pedroni (1999, 2004). Of these seven statistics, three of them are known as the ‘‘between’’ dimension and the other four depend on pooling what is represented as the ‘‘within’’ dimension. Both types test the null hypothesis of no cointegration. However, the differences come from the design of the alternative hypothesis, which is testing the alternative hypothesis $\rho_i = \rho < 1$ on ‘‘within’’, for all i, while concerns based on the ‘‘between’’ dimension, the alternative hypothesis is $\rho_i < 1$ for all i. Pedroni (1999) used Monte Carlo simulations in tabulating the finite sample distribution of seven test statistics. The established statistic tests have to be larger than the tabulated critical value not to reject the null hypothesis of absence of cointegration.

A drawback of the tests offered by Pedroni (1999) is that it is established on the hypothesis of overall factor limitation and that it cannot take feasible cross-country dependency into account. This hypothesis proposes that the short run parameters of the factors in their first differences are equivalent to the long run parameters for the variables in their levels. A failure to suit the limitation leads to a significant decrease of power for the residual based panel cointegration tests (Eggoh, Bangake, & Rault, 2011).

In this research, in addition to applying the Pedroni (2004, 1999) tests, we also use the panel cointegration tests proposed by Kao (1999) to examine the relationship between the variables. The following regression equation presents the measurement of the Kao (1999) ADF type test.

(3.37)

$$e_{it} = \rho\, e_{it-1} + \sum_{j=1}^{p} \gamma ij \Delta e\mathrm{it} - \mathrm{j} + vit$$

Where e_{it}’s are the estimated residuals from the panel static regression equation;

(3.38)

$$Y_{it} = \mu_i + X_{it}' \beta + u_{it};\ i=1,2,\ldots,N:\ t=1,2,\ldots T$$

The alternative hypothesis is H_1: $\rho < 1$, against the null hypothesis of no cointegration is H_0: $\rho = 1$.

3.2.4 **Panel Error Correction Model (ECM)**

The idea of cointegration can be clear as an efficient co-movement among two or more economic variables in the long run. Due to the Engle and Granger (1987) procedure, if the X and Y as variables are both non-stationary, one possibility could expect that a linear approximation of X and Y would be a random walk. However, the two variables may have the characteristic that a particular combination of them Z=X-bY is stationary. Consequently, if such a property holds true, then we profess that X and Y are cointegrated. If X and Y are both non-stationary and the linear combination of two variables is also non-stationary, then the standard Granger causality test should be applicable. Whereas, if X and Y are both non-stationary and cointegrated, then any standard Granger causal inferences will give misleading results, and, thus, a more comprehensive causality test based on an error correction model (ECM) must be applied (Toda & Phillips, 1993).

Our panel data has been set at the industrial level consisting of 21 industries for the period 1990-2007 and at the national level consisting of six countries for the period 1990-2011. The use of an ECM model is mostly suggested in cases in which the time observation (T) is large or both time observations (T) and cross-sectional observations (N) are approximately a similar order of size. This estimator can be practical for separating the short run from the long run effects, which would allow us to estimate the long run impact of ICT on output growth. Our empirical process is composed of (i) evaluating the stationary of the panel variables, (ii) in case the variables are not stationary, we tested for the existence of a cointegrating relationship and (iii) in case cointegration is acknowledged, we are able to carry on by estimating an ECM model. The assessments employed to check for stationary and cointegration are discussed in the results and discussion sections. In this section, we employ the panel ECM using the econometric approach. Firstly, the following Autoregressive Distributed Lag Model ARDL (p, q) model is considered for T periods and N industries or countries:

(3.39):

$$Y_{it}=\sum_{j=1}^{p} \lambda ijYi,t-j+\sum_{j=0}^{q} \delta ijXi,t-j+\mu i+\varepsilon it$$

Where Y is output, X is the vector of the independent variables, μi are fixed effects for each industry or country, λij are the coefficients of the lagged dependent variables and δij are coefficients of current and lagged independent variables. This model yields the following ECM form:

(3.40)

$$\Delta Y_{it}=\pi iYi,t-1+\beta iXi,t-1+\sum_{j=1}^{m-1} \gamma ij\Delta Yi,t-j+\sum_{j=0}^{n-1} \gamma ij\Delta Xi,t-j+\mu i+\varepsilon it$$

Where β_i is the long run parameter for each N, γ_{ij} are the short run coefficients and πi are the ECT parameters. Imposing common β coefficients across industries or countries:

(3.41)

$$\Delta Y_{it}=\pi iYi,t-1+\beta Xi,t-1+\sum_{j=1}^{m-1} \gamma ij\Delta Yi,t-j+\sum_{j=0}^{n-1} \gamma ij\Delta Xi,t-j+\mu i+\varepsilon it$$

Three currently developed techniques for estimating this sort of model, as suggested by Pesaran et al. (1999), are the mean group (MG), the pooled mean group (PMG), and dynamic fixed effect (DFE) estimators. Such panel data estimators are extremely highly recommended in cases that the time point of view (T) is massive or both time observations (T) and cross-sectional observations (N) are approximately a similar order of size. In the long run, with conventional fixed effect estimators, homogeneity of slope coefficients is assumed, while the Mean Group (MG) estimators enable the slopes and intercepts to differ over the cross-sectionals. The Mean Group (MG) estimates the coefficients across each one cross-section and then needs the mean thereof. The Pooled Mean Group (PMG) estimators combine the fixed effects and Mean Group (MG) that permit the short run coefficients to change; however, enforce long run coefficients are equal across sections (N). Hence, the PMG estimator makes it possible for us to estimate a usual long run relationship across sections without notable restricted assumptions of same short run dynamics across sections. Dynamic Fixed Effect (DFE) estimators, like the Pooled Mean Group (PMG) estimators, restrict the coefficients of the long run vector to be equal across all panels (Blackburne & Frank, 2009).

There is a consistency-efficiency trade-off in choosing among MG, PMG, and DFE. While the MG estimators provide consistent estimates of the PMG estimators, they are significantly less efficient in comparison to the mean of the long run coefficients. The PMG estimators are consistent and efficient, when the homogeneity of the long run coefficients is retained. Additionally, the DFE model limits the speed of the adjusted coefficient (ECT) and the short run coefficients to be equivalent, whereas the PMG estimator depends on a combination of pooling and averaging of coefficients. To identify which estimator may be more suitable, we generally rely on the Hausman (1981) specification test and F-test. While we will explain the findings in Chapter 4, various methods are selected among countries and industries.

3.2.5 System GMM and first-difference GMM

The main panel data estimation methods are centred on both random and fixed effect models. It is usually applied to simultaneous accounts that have the presence of time-to-time fluctuations and heterogeneity in the economic performance of cross-sections. In this mean, we discovered that several of the explanatory variables included in the industrial and aggregate level regressions are either endogenous or pre-determined, thus confounding the results.

For instance, as mentioned in section 1.2.5, considering that ICT capital is of an endogenous nature as a General Purpose Technology (GPT), it means that it is very likely that it will have external growth impacts, particularly with lags. This has two meanings: (1) that there might be a dynamic route to ICT's growth impact, so it will only be in the long run that their effects will arise and (2) that there would be a correlation of ICT capital with the error term. Therefore, ICT capital is expected to be an endogenous covariate. Other explanatory variables, like Labour, TFP and Non-ICT, future understanding may be affected due to output growth historical data so that a partial influence might not be orthogonal to the error term of the regression of these variables.

In this situation, biased and inconsistent results are expected to be produced due to the traditional panel data estimation methods (either the random or the fixed effect estimators). New estimation techniques, such as first-difference and System GMM panel data estimators (Arellano & Bover, 1995; Blundell & Bond, 1998) are appropriate due to the correlation between the explanatory variables and historical or even current realizations of the error term (Roodman, 2008).

An unobservable country specific effect is another estimation difficulty in growth equilibriums whose presence has been established in our study. The GMM estimator is also used in an attempt to overcome this problem. Accordingly, a decision is needed as to which variable should be employed as an instrumental variable.

GMM estimators are quite useful in the estimation of panel data with a relatively small time dimension (T) comparative to the number (N) of cross-sections (Roodman, 2008). In contrast, as time observations become greater, misleading and inconsistent coefficient estimates would be provided by the GMM estimator, unless the slope coefficients are equal across cross-sections (Pesaran & Smith, 1995). Through the estimation of separate regression, the problem has been addressed in this study in aggregate level through the use of a comparatively large time dimension (N = 6, T = 22) for the sub-periods of 1990-2000 and 2001-2011. However, for the industrial level study the time observation is relatively smaller, therefore the whole period of panel has been run in this study. This has enabled us to examine the varying effects of ICT across time, and its spillover effects.

It is clear that the augmented extension of the Arellano and Bond (1991) first-difference GMM estimator is the System GMM estimator, which uses endogenous variables lagged levels as instruments. Sometimes the regressor lagged levels are not powerful instruments for the first-differenced GMM regressor. In this case, one should employ the augmented version "System GMM". Generally, the level equation is used to achieve a system of two equations by the System GMM: one in levels and one in differenced. By adding the second equation, supplementary instruments can be gained. Therefore, the variables in levels in the second equation are instrumented with their own first differences, which are usually increasing efficiency.

In conclusion, the System GMM estimators employ the first differences of the instrumented variables as additional instruments. As argued by Arellano and Bover (1995), and Blundell and Bond (1998), the allowance of more instruments in this System GMM estimator can dramatically improve the efficiency of the obtained estimates.

Accordingly, we choose the System GMM in the industrial level data in this research, while we use the first-difference GMM for the aggregate level in this study for two important reasons to be made about using first-difference GMM. First, because System GMM uses more instruments than the difference GMM, it may not be appropriate to employ System GMM with a dataset comprising a small number of countries (aggregate level data with N=6, T=11) (Mileva, 2007). Therefore, we intend to use first-difference GMM for the aggregate level part of the study and System GMM for the industrial level part with large cross-sectional data (N=21, T=17).

In this regard, we employ the System GMM panel data estimator in order to tackle the issue of the endogeneity of repressors in the industrial level panel data with large N (number of industries =21). Next, we quantify the growth effects of ICT by employing the first-difference GMM developed by Arellano and Bond (1991) at the aggregate level that addresses the above-mentioned problems more effectively and obtain robust estimates in the first and two steps for six countries in each group. In this method, lagged values of the dependent and explanatory variables are used as instruments.

The GMM estimator, either the first difference or the system version, has one and two-step variants. The two-step estimator is considered as more efficient; however, the standard errors are downward biased and render GMM estimates useless for inference (Arellano & Bond, 1991). This problem is mitigated in the System GMM version because it incorporates the finite sample correction to the two-step covariance matrix. For this reason, our basic analysis is based on regression, which uses two-step GMM estimators.

The GMM estimators report two diagnostic tests. The first one is the Sargan and Hansen test, which checks for the validity of normal-type instruments and GMM-type instruments. The hypothesis being tested with the Hansen and Sargan tests is that the two types of instruments are uncorrelated with the residuals, and, therefore, are acceptable instruments. If the null hypothesis is confirmed statistically (not rejected), the instruments leave behind the test and are considered valid by this criterion. These estimators also represent a test for serial correlation, which is applied to the first differenced residuals and upper differences. If the null of no autocorrelation is rejected then the test points out that lags of the used instruments are in fact endogenous and are consequently considered 'bad' instruments.

With respect to the number of lags used in the GMM regressions, it is generally adequate that as the number of lags grows, the likelihood of finding proper instruments increases. On the other hand, when the number of moment conditions expands, this leads to a decrease in the size of the sample, bias in the estimates and less power of the diagnostic tests (Roodman, 2008).

To sum up, as pointed out by Roodman (2008), the Arellano and Bond (1991), Arellano and Bover (1995), Blundell and Bond (1998) dynamic panel estimators are progressively more popular. All are common estimators designed for situations with 1) “small T, large N" panels, means few time observations and lots of individuals; 2) a linear functional model; 3) a single left-hand-side variable that is dynamic, depending on its own past observations; 4) explanatory variables that are not strictly exogenous, means correlated with past and possibly current observations of the error term; 5) heteroscedasticity and autocorrelation within individuals but not between them; and 6) fixed individual effects.

The Arellano and Bond (1991) estimation starts by transforming all regressors, usually by differencing and using the Generalized Method of Moments condition, that is called the first-difference GMM. The Arellano and Bover (1995) and Blundell and Bond (1998) estimator augments Arellano and Bond (1991) by creating a supplementary assumption, that the first differences of the instrument variables are uncorrelated with the fixed effects. As a result, allowing introducing more instruments can considerably improve efficiency. It constructs a system of two equations, the original equation as well as the transformed one and is well known as System GMM (Roodman, 2008). In addition, diagnostic tests like over-identification tests and serial correlation tests are applied to ensure there is no bias due to correlation with the error term.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Introduction

The discussion in the econometric methodology section demonstrated that ICT capital is considered as General Purpose Technology (GPT) of an endogenous nature, meaning it will most likely have external growth effects, particularly with lags. This means that the process of growth due to the impact of ICT might be dynamic, thus it will only be in the long run that its impact will surface. In addition, there might be a correlation between ICT capital and error-term.

It appears that because of the endogeneity problem, it is most likely that inconsistent and biased results would be produced via using traditional panel data estimation methods (either the random effect or fixed estimator). In this study, we apply newly developed panel data techniques to quantify the impact on growth of ICT. Firstly, the panel error correction model is estimated to assess the short run and long run effects on output growth by ICT. This approach is commonly used for the detection of causal relationships between variables by applying the Engle-Granger test procedure. To estimate non-stationary dynamic panels, we have used three new techniques – Pooled Mean Group (PMG) estimators, the Dynamic Fixed Effect (DFE) estimators and Mean Group (MG) (M.H. Pesaran, Shin, & Smith, 1999). For the analysis of panel data with time series (T) and cross-section (N), which are of the same order of magnitude and are relatively large, panel data estimators are particularly useful (Blackburne & Frank, 2009).

Before implementation of ECM, we have tested for the presence of unit root in panels, and the issue arises as to whether there is an existence of a long run equilibrium relationship between the variables. Two sets of panel cointegration test methods are used in our empirical analysis. Pedroni (2004) proposed the first set of tests. A generalised Augmented Dickey-Fuller (ADF) test is the second set of tests proposed by

Kao (1999) in the panel data framework. The results of these two tests have suggested no possibility of cointegration under the null hypothesis while employing the residuals derived from a panel regression so as to establish the distributions and make the test statistics.

Next, in order to overcome the issue of endogeneity in the long run causal relationship between ICT and economic growth, system GMM and first-difference GMM panel data estimator will be used. We will assess the value added growth at the aggregate level, through TFP and some controlling variables in order to cover the spillover effects of ICT by using System GMM as well.

4.2 Reasons for Choice of Countries

The main purpose of this research is to assess the comprehensive ICT effects on economic growth with regards to the top ICT developed countries in Asia-Pacific and Europe. According to the literature, there are many works on comparative studies on the EU and US. In these studies, the ICT development index has been disregarded, especially in Asia-Pacific countries at the industrial level panels. To fill this gap, we collect aggregate level data for 12 top ranked ICT developed countries in EU and Asia-Pacific countries from the World Bank Indicator (WDI) database. To execute the same analysis at the industrial level we have some limitations in the data collection process.

In Asia-Pacific countries, from the six top ranked ICT developed countries, as illustrated in Table 4-1, we only succeeded in collecting data for Japan and Australia. In the EU zone countries, from the six top ranked ICT developed countries, as illustrated in Table 4-1, we only succeeded in collecting data for Sweden, Denmark, and Finland. This study relies on the International Telecommunication Union (ITU) in the 2010 ranking of ICT developed countries. To be more precise, we have used the EU KLEMS database as the unique database in order to capture high reliability for our datasets.

Table 4-1. Six top ranking of ICT development index(IDI) among EU and Asia-Pacific countries

European Economy	Regional Rank 2010	GlobalRank 2010	Asia-Pacific Economy	Regional Rank 2010	Global Rank 2010
SWEDEN	1	2	KOREA(REP)	1	1
ICELAND	2	3	HONG KONG	2	6
DENMARK	3	4	NEW ZEALAND	3	12
FINLAND	4	5	JAPAN	4	13
LUXEMBOURG	5	7	AUSTRALIA	5	14
SWITZERLAND	6	8	SINGAPORE	6	19

Source: International Telecommunication Union (ITU), 2011

Therefore, we will classify our results at the industrial level and aggregate level in general. The industrial level findings are shown in the analysis for each individual county whereas the aggregate level findings revealed two groups of results for the panels of Asia-Pacific and EU countries. We will start discussing the results for industrial level analysis of five ICT index developed countries in the following sections. Subsequently, the aggregate level analysis will follow the other two regions.

4.3 Japan – Growth Decomposition

Annual GDP growth (EG) and relative contribution of labour capital, ICT capital, non-ICT and TFP among Japanese industries over 1990-2007 are illustrated in Table 4-2 based on the EU KLEMS (2012) database analysis.

Japan is one of the most developed ICT countries in the Asia-Pacific region. From 1990 to 2007, the average annual economic growth was over 0.68 per cent. The contribution of non-ICT capital services to GDP growth was 1.06 per cent whereas the contribution of ICT capital services and labour composition index to GDP growth over these years were 0.28 per cent and -1.24 per cent, respectively. The Japanese economy has been in recession since 1990. The 1990s was called the 'lost decade' for Japan. Recently, in order to escape from recession, the Central Bank of Japan intends to increase the inflation rate . The only slump in Japan's economy was in 1998 and 1999 when the economy was severely affected by the Asian financial crisis [9] and the global financial crisis of 2008-2009. Japan’s GDP growth decreased at -1.165 per cent in 2008, and further dropped to -6.288 per cent in 2009. However, in 2010, it increased dramatically to 4 per cent. The upsurge in GDP growth in 1990 (5.20 per cent) and 2010 (4 per cent)[10] was accompanied by an increasingly huge contribution of ICT with respect to non-ICT capital and labour services in those years. Therefore, capital deepening in Japan was caused by the rapid accumulation of ICT capital.

Table 4-2. Japan growth decomposition

Variable	Obs	Mean	Std. Dev.	Min	Max
EG(%)	357.00	0.68	6.04	-25.66	23.43
L(%)	357.00	-1.24	2.27	-11.96	3.03
ICT(%)	357.00	0.28	0.55	-0.11	5.43
non-ICT(%)	357.00	1.06	1.22	-1.17	5.50
TFP(%)	357.00	0.24	5.20	-26.53	25.01

Source: EU KLEMS Database, 1990-2007

Fukao et al. (2009) argued that Japan suffered a rigorous stagnation through the latter period, resulting from three aspects contributing to the recession in the market. The deceleration in TFP was responsible for 8 per cent of the downturn, when the negative contribution of labour and decrease in the contribution of ICT input growth accounted for -44 per cent and 10 per cent of the slowdown, respectively. In line with the results of Fukao et al. (2009), EU KLEMS statistics also show in detail that, on average, the ICT contribution rate dropped 0.262 per cent, from 0.43 per cent to 0.30 per cent between 1990 and 2007 in Japan.

Generally, sources of output growth can be grouped into three main channels: i) contribution of capital input, which consists of non-ICT and ICT capital; ii) Contribution of labour input (L), and iii) Contribution of TFP growth. Figure 4-1 illustrates the share sources of output growth for Japanese industries over 1990-2011.

[9] See more information on the website of the World Bank, World development indicators for 1990-2011. Washington, DC: World Bank; 2012.

[10] The growth accounting analysis for the Japanese economy in this section is based on the EU KLEMS Database, October 2012. For details regarding this database see Timmer et al. (2007).

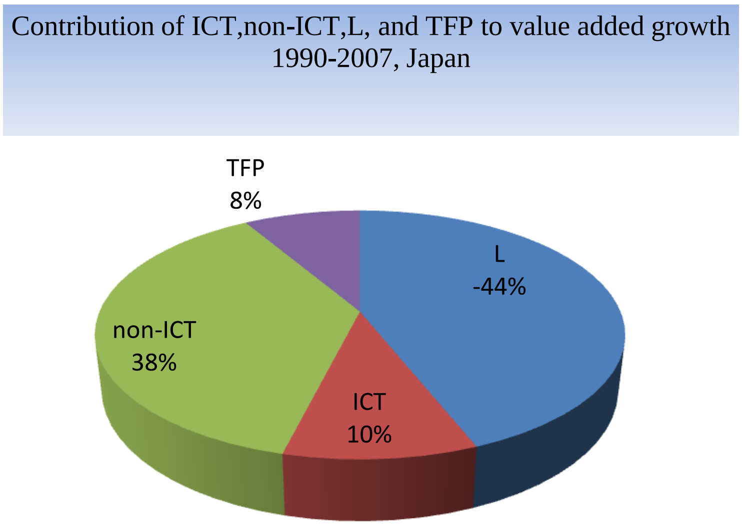

Figure 4-1. Contribution of ICT, non-ICT, Labour, and TFP to value added
Source: EU KLEMS Database, 1990-2007

To sum up the above analysis, Japan, as a leading country in ICT-producing industries has less contribution of ICT (only 10 per cent) relative to other input factors. Therefore, there is the possibility of a high difference in the contribution of the input factor growth that caused the large difference between the GDP growth performance of Japanese industry over the period. Japan, like the EU economies, experienced a slowdown in TFP contribution growth (8 per cent) to value added growth during the period whereas, we identified from the previous findings that the problem is in TFP growth in ICT-using industrial sectors, similar to the distribution services (retail, wholesale and transportation). The rest of the manufacturing sector (i.e. excluding electrical machinery), has diminished substantially. These types of ICT-using industry have a greater share of the overall economy than the ICT-producing industry (Fukao et al., 2009).

4.3.1 **Japan – panel unit root tests**

The different panel unit root tests have some statistical weaknesses regarding size and power characteristics, therefore it is more suitable for us to execute several unit root tests to provide overpowering evidence to discover the order of integration of the panel variables. Although several panel unit root tests have been recommended, we applied the panel unit root tests presented by Maddala and Wu (1999), Breitung (2000), Levin-Lin-Chu (2002), Hadri (2000), and Pesaran (2003).

Table 4-3. Japan panel unit root tests

Method	EG	L	ICT	Non-ICT	TFP
Breitung (2000)					
Level	0.076(0.530)	-0.348(0.364)	-2.406*(0.008)	0.136(0.554)	-1.514**(0.065)
First difference	-2.262*(0.012)	-3.306*(0.001)	-2.805*(0.003)	-2.070*(0.019)	-2.0445*(0.021)
Hadri(2000)					
Level	3.105*(0.001)	3.733*(0.000)	3.759*(0.000)	22.385*(0.000)	1.583**(0.057)
First difference	0.112(0.455)	1.188(0.117)	0.690(0.245)	-2.248(0.988)	0.183(0.428)
Pesaran (2003)					
Level	2.628 a(0.996)	1.165a(0.878)	1.874 a(0.970)	-1.236 a(-1.236)	4.613a(1.000)
First difference	-3.530a*(0.000)	-16.384a*(0.000)	-4.887 a*(0.000)	-1.236a*(0.000)	-261.458a*(0.000)
Maddala & Wu(1999), Fisher					
Level	-0.068(0.4730)	-1.060(0.145)	0.491(0.688)	1.912(0.972)	-1.943*(0.026)
First difference	-6.243*(0.000)	-6.397*(0.000)	-1.609**(0.054)	-3.557*(0.000)	-7.446*(0.000)
Levin-Lin-Chu(2002)					
Level	0.897(0.815)	0.278(0.609)	-1.243(0.107)	-0.613(0.270)	1.519(0.936)
First difference	-18.766*(0.000)	-3.546*(0.000)	-11.645*(0.000)	-5.072*(0.000)	-7.295*(0.000)

Notes: The null hypothesis is that the series is a unit-root process except the Hadri (2000) test.
P-values are given in parentheses.
The probabilities for the Fisher-type tests are computed using an asymptotic Chi-square distribution. All the other tests are assumed to be asymptotic normal. The lag length is selected using the Modified Schwarz Information Criteria.
* Indicates the parameters are significant at the 5% level.
**Indicates the parameters are significant at the 10% level.
[a]all of values are z (t-bar).

Source: Author, 2013

Generally, the results in Table 4-3 prove that all five variables are panel non-stationary apart from ICT and TFP in the Breitung (2000), Maddala and Wu (1999) tests. However, the Breitung (2000), Maddala and Wu (1999) tests suggested that ICT and TFP are stationary at level. Based on the Breitung (2000), Maddala and Wu (1999) tests, the analyses show the test statistics at level for the value added growth (EG), contribution of non-ICT and labour are statistically insignificant while ICT and TFP recorded a significant result. It must be pointed out that, in contrast to the other four tests, the Hadri (2000) test depends on the null hypothesis of stationary. While we have certainly employed the panel unit root tests to the first difference of variables, all four tests rejected the joint null hypothesis for all variables. Therefore, regarding the results of all tests, variables are integrated in I(1). Without being explicit in our judgment about the level of variable integration, we run the panel cointegration tests.

4.3.2 Japan – panel cointegration tests

After the evolution of the unit root in panels, the concern arises whether or not there is a long run equilibrium relationship between the variables. In our empirical testing, we apply two sets of cointegration test techniques. The first set is suggested by Kao (1999), which is a generalisation of the ADF tests in the prospect of panel data. The second set of tests is proposed by Pedroni (2004). These presented tests consider the null hypothesis of no cointegration and work with the residuals derived from a panel regression to develop the test statistics and figure out the distributions.

Table 4-4. Kao's residual cointegration test results

	Lag [a]	t-statistic	Probability
ADF	3	-11.785*	0.0000

Note: Null Hypothesis: No cointegration,
[a] lag selection using Parzen kernel,
*Indicate that the parameters are significant at the 5% level.

Source: Author, 2013

The Kao (1999) test results in Table 4-4 reveal the rejection of the null hypothesis; hence, the existence of cointegration among the variables is confirmed. Seven cointegration tests have been proposed by Pedroni (1999) that can be applicable for panel data in the non-existence of structural breaks in the data. These comprise the panel v-statistic, panel rho-statistic, panel PP-statistic (non-parametric), panel ADF-statistic (parametric), group rho-statistic, group PP-statistic (non-parametric) and group ADF-statistic (parametric). It has been recommended to remove the common time effects before running the cointegration tests by Pedroni (2004).

Table 4-5. Pedroni's (2004) residual cointegration test

	Statistic	Prob.
Panel v-Statistic	3.005759*	0.0013
Panel rho-Statistic	0.020414	0.5081
Panel PP-Statistic	-3.388716*	0.0004
Panel ADF-Statistic	-6.046886*	0.0000
	Statistic	Prob.
Group rho-Statistic	1.027167	0.8478
Group PP-Statistic	-6.067454*	0.0000
Group ADF-Statistic	-6.167375*	0.0000

Notes: The null hypothesis is that the variables are not cointegrated.
Under the null tests, all the statistics are distributed as normal (0, 1).
*Indicate that the parameters are significant at the 5% level.

Source: Author, 2013

The findings of Pedroni's (2004) panel cointegration test are reported in Table 4-5. Five of the seven Pedroni (2004) tests disclosed evidence of cointegration. Therefore, without providing structural breaks in the number of series based on the Pedroni (2004) test we can confirm that there is a long run cointegration relationship among the panel variables.

4.3.3 **Japan – panel Granger causality results**

The cointegration relationship denotes the presence of a causal relationship; however, it fails to imply the direction of the causal relationship between variables. Therefore, it can be common to test for the causal relationship between variables employing the Engle-Granger test technique. Given the use of a Vector Error Correction Model (VECM), all the variables are treated as endogenous variables in equations (3.22)-(3.26). The mentioned equations are estimated by employing either the Pooled Mean Group (PMG) or the Dynamic Fixed Effect (DFE) proposed by Pesaran et al. (1999). We have chosen the proposed estimation method of Hausman for which the F-test results are given below in Table 4-6. This test refers to the causal relationship in the short run and long run Granger causality results, as reported below in Table 4-6.

Table 4-6. Panel causality test results for Japan

Dependent Variable	*Source of Causation (independent variable)*						*Estimation Method Based on Hausman Test*
	Short Run					*Long Run*	
	ΔEG	ΔL	ΔICT	Δnon-ICT	ΔTFP	ECT	
ΔEG	-----	0.4505* (0.000)	-0.0986 (0.755)	0.5223* (0.000)	0.4032* (0.000)	-0.5778* (0.000)	*PMG*
ΔL	0.4051* (0.000)	-------	-0.1092 (0.776)	-0.4643* (0.000)	-0.4091* (0.000)	-0.5172* (0.000)	*PMG*
ΔICT	0.1137** (0.056)	-0.1053** (0.066)	------	-0.0470 (0.416)	-0.1141** (0.057)	-0.3052* (0.000)	*PMG*
Δnon-ICT	0.0792* (0.007)	-0.1289* (0.000)	0.1437 (0.442)	-------	-0.0804** (0.003)	-0.3424* (0.000)	*DFE*
ΔTFP	0.2674* (0.000)	-0.2838* (0.000)	-0.1575 (0.229)	-0.3855* (0.000)	--------	-0.7419* (0.000)	*DFE*

Note: The reported values in parentheses are the p-values of the F-test.
*indicates significant at the 5% level, **indicates significant at the 10% level.

Source: Author, 2013

The F-test is employed to establish whether a short run and long run causality relationship exists among the variables via examining the significance of the lagged levels of the variables. Based on equations (3.22)-(3.26), we set nulls for each equation as H_0: $\beta_{1=}\ \beta_{2=}\ \beta_{3=}\ \beta_{4=}\ \beta_{5=0}$ versus H_1: $\beta_1 \neq \beta_2 \neq \beta_3 \neq \beta_4 \neq \beta_5 \neq 0$ in the short run and H_0: $\lambda i=0$ versus H_1: $\lambda i \neq 0$; i=1,2,..,5 in the long run. The computed F-statistics under the null hypothesis of no long run causality relationship are denoted as F (EG| L, ICT, non-ICT, TFP), F (L| EG, ICT, non-ICT, TFP), F (ICT| EG, L, non-ICT, TFP), F (non-ICT| EG, L, ICT, TFP), and F (TFP| EG, L, ICT, non-ICT) for each equation, respectively. The Schwarz Information Criterion is used for selecting the optimal lag length. It is known that a standard F-test is appropriate to test the null hypothesis that fed the stationary variables for testing causality.

With regards to the ICT influence on output growth, we have determined that the estimated short run impact for the period 1990-2007 is negative and insignificant. Particularly, its size suggests that a 1 per cent increase in ICT capital results in 0.098 per cent reductions in output growth. Among 21 industries in Japan, ICT is only considered as significant and positive capital in six industries, of which most are in the transport, storage, post and telecommunication sectors. We even noticed that the effect of non-ICT capital is significantly positive. Theoretically, once the latest dramatic modernisation (like ICT) comes, an overall economy is afflicted with preliminary economic loses (Dimelis & Papaioannou, 2011).

With respect to the TFP results in the last row, the impact of ICT on TFP is negative (-0.157) and insignificant in the short run while non-ICT and labour are significant and negative (-0.386, -0.284). Empirically, Esteban-Pretel et al., (2010) found decreasing productivity coupled with the reduction in hours worked, which cause a drop in employment and output.

Lower productivity in service industries has been found by Fukao et al. (2009), Shinjo and Zhan (2004) via estimation of multifactor productivity in the economy of Japan influenced by the dataset of 72 industries following the EU KLEMS project guidelines, which experienced a “Lost Decade” and a financial crisis in 1997-1998. Moreover, it could be stated that the reported ECT coefficients in the last column are negative and statistically significant. The sign of the coefficient of the error correction term must be negative to provide stability for the model. We expect the coefficient to be negative and smaller than one. As Narayana (2011) stated, if the coefficient of the error correction term is smaller than one, then the system is equilibrating by fluctuating and this waving will decrease in each term before providing the transition to equilibrium. ECT coefficients are negative and statistically meaningful, as expected, in nearly all of the models.

For instance the ECT coefficient for the EG model in the first row is -0.57. This value of speed of adjustment was inside of what we expected. This shows that the speed of adjustment is less than enough with 57 per cent to reach the long run equilibrium level in response to the disequilibrium caused by the short run shocks of the previous period. In addition, the speed of adjustment is relatively slow for Japanese industries.

Table 4-7. Panel industries direction of causality in the short run and long run, Japan

Short Run causality		*Long Run causality*	
Direction of Causality	*Wald F-test*	*Direction of Causality*	*Wald F-test*
ΔEG ←——→ ΔL	(0.000)* (0.000)*	EG ---------→ L	(0.000)* (0.000)*
ΔEG ----------→ ΔICT	(0.755) (0.056)**	EG ←--------→ ICT	(0.000)* (0.000)*
ΔEG ←——→ Δnon-ICT	(0.000)** (0.007)**	EG ←-------→ non-ICT	(0.000)* (0.000)*
ΔEG ←——→ ΔTFP	(0.000)* (0.000)*	EG ←-------→ TFP	(0.000)* (0.000)*
ΔL ---------→ ΔICT	(0.776) (0.066)**	L ←-------→ ICT	(0.000)* (0.000)*
ΔL ←——→ Δnon-ICT	(0.000)* (0.000)*	L ←-------→ non-ICT	(0.000)* (0.000)*
ΔL ←——→ ΔTFP	(0.000)* (0.000)*	L ←-------→ TFP	(0.000)* (0.000)*
ΔICT no causality Δnon-ICT	(0.416) (0.442)	ICT ←-------→ non-ICT	(0.000)* (0.000)*
ΔICT ←------- ΔTFP	(0.057)** (0.229)	ICT ←-------→ TFP	(0.000)* (0.000)*
Δnon-ICT←——→ΔTFP	(0.003)* (0.000)*	non-ICT ←-------→ TFP	(0.000)* (0.000)*

Note: The reported values in parentheses are the p-values of the F-test.
*indicates significant at the 5% level, **indicates significant at the 10% level.

Source: Author, 2013

The results in Table 4-7 show the long run bidirectional Granger causality running from real GDP growth to the contribution of L, ICT, non-ICT, and TFP growth at the per cent significant level. Except ICT capital, there is a bidirectional Granger causality relationship among the contribution of L, ICT, non-ICT, and TFP growth to value added growth in the short run as well. As a result, in line with the findings of Fueki and Kawamoto (2009), and Miyagawa, Ito, and Harada (2004) at the industrial level, we found that the increase in overall TFP growth certainly emerges from a rise in technological change. The findings in Table 4-7 indicate that there is panel short run bidirectional causality among L, non-ICT and TFP, which means that non-ICT and labour contribution could be an effective factor on TFP growth in 1990-2007. There is no causality relationship between ICT and non-ICT capital during the period in the short run.

We conclude that the short run results for causality are significantly weak; nevertheless, the long run outcomes are highly significant. The long run results concerning the impact of ICT on GDP growth is inconsistent with those of Elsadig (2010) for a panel of ASEAN 5 – Malaysia, Indonesia, Philippines, Singapore and Thailand, plus 3 countries – China, Japan and South Korea (Shimizu, Ogawa, & Fujinuma, 2006).

4.3.4 **Japan – long run relationship by System GMM**

The GMM estimator, either the system or the first difference version, possesses one and two-step categories. The two-step estimator is approximately more efficient; but the standard errors are downwards biased and cause the GMM estimates to be ineffective for inference (Arellano & Bond, 1991). This issue is mitigated in the System GMM version since it includes the finite sample correction to the two-step covariance matrix (Windmeijer, 2005). For this reason, the results of the two-step System GMM estimators in columns (3) and (4) are more significant and efficient.

Equation (3.2) could be further augmented by qualitative details constructed as binary variables implying whether an observation originates from an ICT-producing or ICT-using industry. The reason for the utilisation of such qualitative information might be derived from Jorgenson and Stiroh (2003), who argued that much of the latest US growth renaissance occurred in industries producing. Thus, the "electrical and optical equipment" industry is introduced as an ICT-producing industry in our research. Extensive ICT-using industries were considered while the coefficient of ICT capital becomes significant in the PMG estimations results, which are listed as "transport and storage, communication", "post and telecommunications", "electrical and optical equipment", manufacturing and recycling", "electricity, gas and water supply", and " other non-metallic mineral" industries for Japan. Thus, ICT_PROD and ICT_USE, which are included as binary variables, show that the returns to ICT are higher in ICT-producing than ICT-using industries.

Table 4-8. Long run panel data estimators for industries, Japan

Independent Variables	*Dependent Variable:EG*			
	System GMM Estimates, One-step		*System GMM Estimates, Two-step*	
	(1)	(2)	(3)	(4)
L	1.019* (0.000)	1.010* (0.000)	1.019* (0.000)	0.987* (0.000)
ICT	1.689* (0.003)	0.782 * (0.000)	0.707 (0.210)	0.748* (0.000)
Non-ICT	0.969* (0.000)	1.053 * (0.000)	0.961* (0.000)	1.100* (0.000)
TFP	1.008* (0.000)	1.023* (0.000)	1.00* (0.000)	1.022* (0.000)
ICT_PROD	1.702 (0.218)		2.277** (0.077)	
ICT_USE	-1.063 (0.218)		-0.249** (0.762)	
ICT_nonICT	-0.116 (0.766)		0.150 (0.556)	
Constant	0.327* (0.008)	0.356* (0.004)	0.373* (0.003)	
Obs	357	357	357	357
Industries	21	21	21	21
Wald test	6902.62	1718.31	52049.54	2895.43
Sargan test(p-value)[a]	1.000	1.000	1.000	1.000
Hansen test (p-value)[b]	1.000	1.000	1.000	1.000
Serial correlation test AR(1) (p-value)[c]	0.108	0.104	0.107	0.085
Serial correlation test AR(2) (p-value)[d]	0.314	0.320	0.309	0.317

a. Sargan test is evaluating overidentifying restrictions in Ivs. The null hypothesis is that the instruments used in the regression are valid.
b. Hansen test is evaluating overidentifying restrictions in GMM. The null hypothesis is that the instruments used in the regression are exogenous.
c. d. The null hypothesis is that the error in the first-difference regression exhibit no first or second order serial correlation.
The values in parentheses denote the significance level for rejection.
*Indicate that the parameters are significant at the 5% level.
**Indicate that the parameters are significant at the 10% level.

Source: Author, 2013

Columns (1) and (3) show the regression results subsequent to including the interaction terms between the binary variables and ICT capital. From the reported results in column (3), it seems that the ICT contribution effects were significantly higher, positive and rather considerable in ICT-producing (2.277) with respect to ICT-using (-0.249) industries. Furthermore, when contemplating the specific impacts of ICT in ICT-producing and ICT-using sectors, the impact of ICT turns insignificant as well. We may conclude, like Jorgenson et al. (2003), and Van Ark et al. (2003), that the positive impact of ICT is mainly centred on ICT intensive industries (Jorgenson et al., 2003). Moreover, the insignificant ICT coefficient in column (3) shows that the adoption of the Japan economic system with the diffusion of new ICT was weak and prove that the contribution of conventional capital like non-ICT and labour to annual economic growth is more than ICT capital.

In spite of the above, we plan to examine the complementary hypothesis between ICT and non-ICT capital by inserting in their interaction term (ICT_non-ICT) as an independent regressor. The results prove that no significant complementary impacts can be found between ICT and non-ICT capital. On the other hand, the reported findings in the last column are in line with the PMG short run results of Table 4-6, which shows that the growth of ICT capital contribution in Japan is less than other capital to value added growth between 1990 and 2007.

The reported results of the System GMM estimators present two diagnostic tests – the Sargan and Hansen tests, which check for the validity of normal-type instruments and GMM-type instruments. The hypothesis examined with the Hansen and Sargan tests is that the two kinds of instruments are uncorrelated with the residuals, and, therefore, are appropriate instruments. Our null hypothesis proved that the instruments pass the test and are regarded as valid by this criterion. This estimator additionally records a test for the first and second serial correlation, which is employed on the first differenced residuals. If the null of no autocorrelation is not rejected then the test implies that lags of the employed instruments have been in fact exogenous and thus are found to be ‘good’ instruments.

4.3.5 Justification of insignificant effects of ICT on TFP and GDP growth in Japan

As mentioned in the literature, the aggregate and sectoral growth accounting exercises suggest stronger differences of the ICT effect between the Asia-Pacific and European countries. ICT-using and -producing industries have a significant effect on growth through ICT in Japan. The average growth rate of value added for each industry by individual country has been illustrated in the figure, which is based on EU KLEMS data. According to Figure 4-2 the "textiles, leather and footwear" industry in Japan has the highest proportion of value added growth by an average 17 per cent growth rate per year compared to the other sectors, whereas the textile sector is neither a ICT-producing nor ICT-using sector. Thus, the growth of ICT-using and -producing industries has become an insignificant factor to GDP growth since the economic growth of Japan is affected by "textiles, leather and footwear" as the main productive sector. However, our synthetic analysis from Figure 4-2, PMG and GMM estimator results suggest that Japan must stimulate increasing the ICT contribution of those industries that have a positive impact on GDP growth, especially ICT-using industries, such as "post and telecommunications" industry due to the high share of GDP growth.

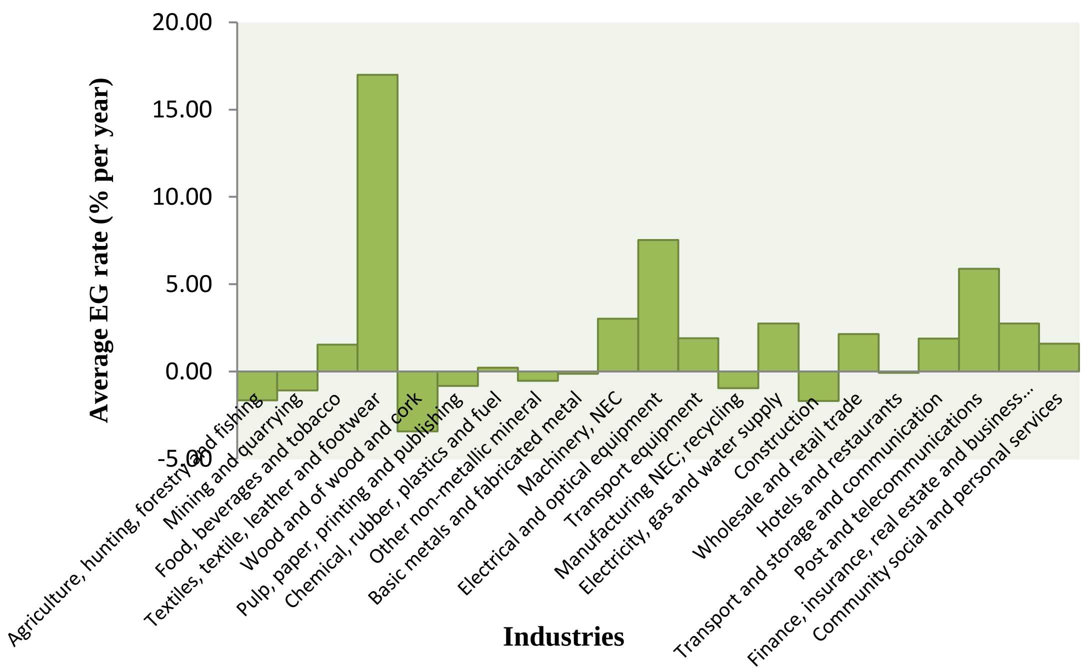

Figure 4-2. Average growth rate of value added for each industry, Japan
Source: Author Analysis, 2013

The spillover effects of ICT have been reported through TFP growth. The spillover effects of ICT are not effective, firstly because of the fact that TFP has less share of the output growth of Japanese industries, and, secondly, the low number of industries that are ICT-using. From 21 classified industries, only six have a positive significant effect of ICT, which are all ICT-using sectors. On the other hand, based on the unidirectional granger causality running from TFP growth to ICT contribution, there is still a productivity paradox for the Japanese sectors, which is the consequence of negative insignificant effects of ICT on TFP. The positive significant effects of TFP on GDP growth in the long run may not attribute to ICT growth. This can be interpreted as there being no evidence to prove the absence of spillover effects of ICT for Japanese industries that leads to a significant effect of ICT on GDP growth. All of these findings show that ICT does not have a significant effect on value added growth.

The overall proportion of ICT-using industries in Japan, such as "transport, storage and communication", "post and telecommunications", "electricity, gas and water supply" from GDP growth are more than other industries; therefore, the output growth rate would be increased if ICT-using industries have been stimulated to penetrate and investment in ICT. Therefore one of the suitable policy implications can be to stimulate penetrating and investing in ICT, such as the “textiles, leather and footwear” industry, which is capable of increasing GDP growth.

Two decades ago, Japan was acknowledged to be a popular ICT-producer. Nowadays, Japan's economy is weak in both ICT-producing and using sectors. It seems that a lack of competition and excessive regulations in the public service sector have hindered the effects of ICT-usage and also the quest for renewed sustainable growth paths while lowering the productivity in the service industries. It has been found in this study that the main reason behind Japan’s lost decade is the slow-down of TFP. Growth in Japan’s TFP is now believed to be primarily supported by the ICT-using industries. Recently, Japan is losing its advantages in telecommunication infrastructure and also lagging behind in availability and utilisation, as shown in Figure 4-3.

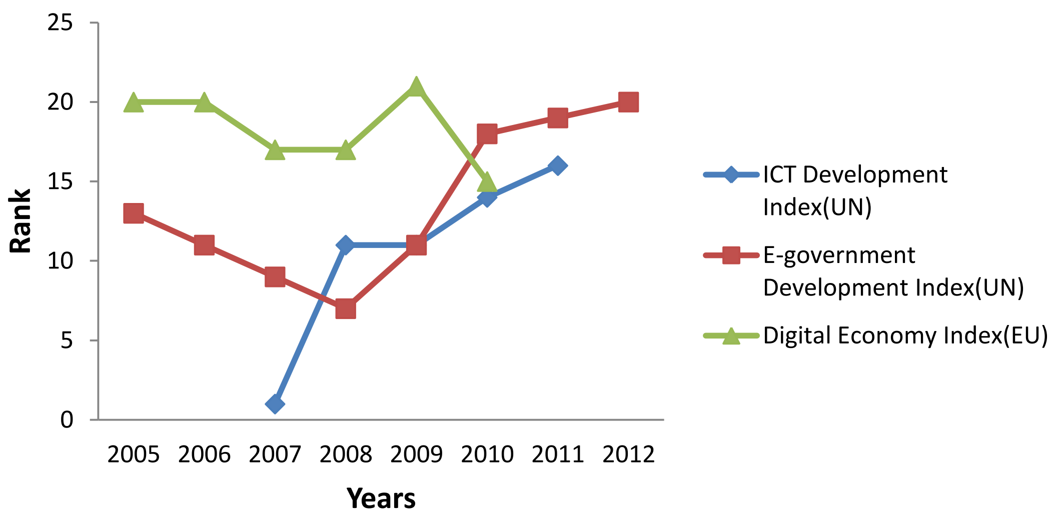

Figure 4-3.Ranking trends in major international ICT indices
Source: Ministry of Internal Affairs and Communications of Japan, 2012

Based on the report of the "Ministry of Internal Affairs and Communications of Japan, 2012", on ICT utilisation, Japan is gradually lagging behind further, especially in the private and public sectors where the lag has become apparent, as illustrated in Figure 4-4.[11]

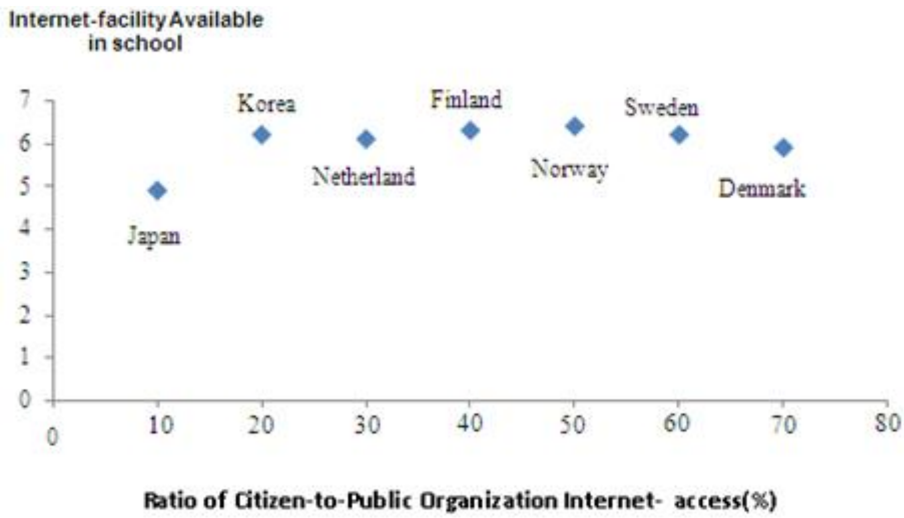

Figure 4-4.Utilization in Public Sector for Japan, 2010
Source: Ministry of Internal Affairs and Communications of Japan, 2012

In addition, in terms of the Internet-based business communication among industries in the public sector, Japan is ranked lowest among the 18 countries investigated.

11See more in "White Paper Information and Communications in Japan, 2012"

According to this report, Japan's export ratio is low in both hardware and service industries. Japan's ICT industry has steady good performance in the software/service sector but is sluggish in the hardware sector (particularly in exports), as the industry is becoming domestically oriented. Japan's ICT-export-coefficient having remained positive for many years, was negative in 2011, especially for video equipment (TVs, etc.) and communication equipment (mobile phones, etc.). The domestic demand for information or telecommunication services shows steady growth. On the other hand, the foreign demand, especially for hardware, is declining (White Paper Information and Communications in Japan, 2012).

Moreover, Japan's ICT corporations are gradually sliding down in the corporate ranking measured on stock-market capitalisation or sales growth rate. While the worldwide telecom-service providers or ICT vendors are seeking growth by entering into the overseas markets, including those in developing countries, the pace of overseas market cultivation by Japanese corporations is slow. Based on Figure 4-5 and 10 breakdowns of contribution of ICT to GDP and TFP, growth is considerable between 2004 and 2009.

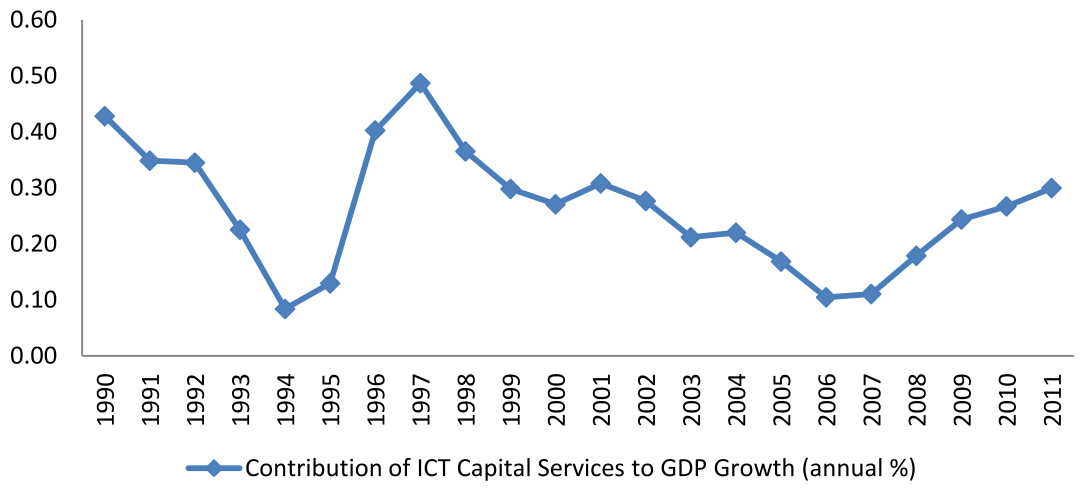

Figure 4-5.Contribution of ICT Capital Services to GDP Growth (annual %)
Source: Ministry of Internal Affairs and Communications of Japan, 2012

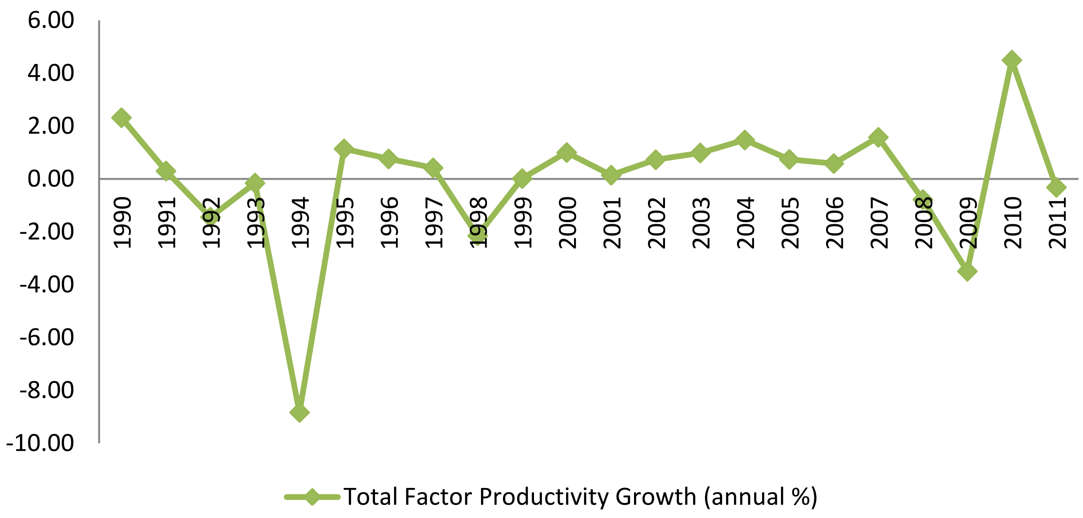

Figure 4-6.Total Factor Productivity Growth (annual %)
Source: Ministry of Internal Affairs and Communications of Japan, 2012

Japan's overall economy has a powerful ICT-producing industry but fairly weak ICT-usage impact (Fukao et al., 2009). Therefore, decreased productivity in the service sector as a result of unnecessary regulations and low competition in public service industries appears to have been employed against improving ICT-usage impact and obtaining renewed sustainable growth pathways. The resource reallocation impacts of capital input in Japan were either insignificant or negligible.

The Great East Japan Earthquake in 2011 had a huge impact on the society and economy of Japan. Now, while Japan is facing various challenges, such as population decline and population ageing, the following activities are required for Japan's re-birth in ICT-using and producing industries. Local governments pay attention to "prompt and firm information provision" as a serious challenge of information provision to the residents after the earthquake. After the earthquake, about 70 per cent of the local governments decided to enhance the utilisation of the Internet showing that they have altered their policies.[12]

[12]See more in "White Paper Information and Communications in Japan, 2012"

4.4 Sweden – Growth Decomposition

The growth in productivity of the Swedish manufacturing sector has been one of the highest among European countries since the beginning of the 1990s. According to the European Innovation Scoreboard, Sweden is thought to be the leading innovator in ICT (Hollanders & Cruysen, 2008). As opposed to the period of economic stagnation between 1960 and 1990, the Swedish economy is performing much better.

Table 4-9. Sweden's growth decomposition

Variable	Obs	Mean	Std. Dev.	Min	Max
EG(%)	294	3.883367	7.117105	-13.81	44.75
L(%)	294	0.01915	2.645781	-14.36	9.74
ICT(%)	294	0.416973	0.523966	-0.37	3.32
non-ICT(%)	294	1.172993	2.205201	-7.76	15.04
TFP(%)	294	2.132585	7.32502	-21.65	50.31

Source: EU KLEMS Database, 1990-2007

The contribution of TFP growth and relative contribution of ICT, non-ICT, labour to GDP growth in Sweden between 1990 and 2007 are illustrated in Table 4-9 and Figure 4-7. ICT with a minimum standard deviation has the smallest fluctuation among the other effective components of economic growth and its spillover effects through its significant TFP contribution of 57 per cent to economic growth.

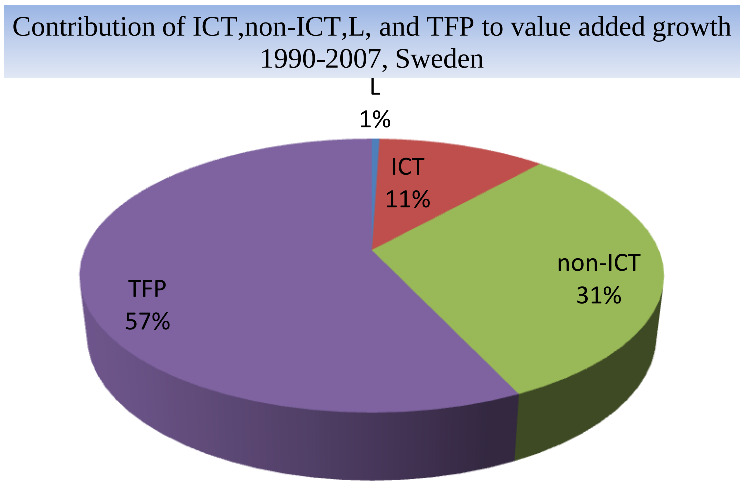

Figure 4-7. Contribution of ICT, non-ICT, Labour, and TFP to value added
Source: EU KLEMS Database, 1990-2007

The average annual growth rate from the start of 1990 to the end of 2011 in the productivity of the manufacturing sector increased to a high of 1.55 per cent from -1.09 per cent (World Development Indicators). During the 1990s, the declining trend of productivity growth was an international phenomenon. However, the case of Sweden is exceptional. It is a very well-known fact that to increase total factor productivity, the role of sustainable improvement in the supply of factors is very important. The factors of supply includes process and product technology, especially IT technology, and also skills and innovativeness (Oh, Heshmati, & Lööf, 2009). The high long run growth of an economy is yielded by the increase in TFP growth. The gradual increase in the productivity of the Swedish economy reflects the sustainable improvement in growth in this respect (3.88 per cent).

4.4.1 **Sweden panel unit root test**

We performed the panel unit root tests proposed by Maddala and Wu (1999), Breitung (2000), Levin-Lin-Chu (2002), and the Pesaran (2003) panel stationary tests for cross-sectional dependence and independence.

According to the results in Table 4-10, we can claim that none of the variables are stationary at level and they are integrated at first difference I (1). We also implemented the panel stationary test without structural breaks, which is identical to the Hadri (2000) panel stationary test. This test relies on the residuals from the particular OLS regressions. However, under the null hypothesis, if it does not have any unit root and the series is stationary, even though, under the alternative, unit root exists. Therefore, the null is not rejected at level.

Table 4-10. Panel unit root tests, Sweden

Methods	EG	L	ICT	Non-ICT	TFP
Breitung (2000)					
Level	-1.331**(0.091)	-0.816 (0.207)	-1.192 (0.117)	0.182 (0.572)	-1.214 (0.113)
First difference	-2.472* (0.007)	-1.996*(0.023)	-0.899 (0.184)	-1.462**(0.072)	-2.095*(0.018)
Hadri (2000)					
Level	3.314*(0.001)	3.157*(0.001)	6.385*(0.000)	5.305*(0.000)	2.161*(0.015)
First difference	1.249 (0.106)	1.878 (0.030)	0.234(0.408)	0.134(0.447)	0.677 (0.249)
Pesaran (2003)					
Level	-0.038 (0.485)	-0.666(0.253)	-1.784*(0.037)	2.326(0.990)	1.338(0.910)
First difference	-1.771*(0.038)	-4.486a*(0.000)	-4.406 a*(0.000	-1.716a*(0.043)	-1.764a*(0.039)
Maddala & Wu(1999), Fisher					
Level	1.848*(0.032)	0.442(0.329)	1.729*(0.042)	-0.687(0.754)	0.490(0.312)
First difference	7.164*(0.000)	9.103*(0.000)	15.815*(0.000)	3.733*(0.000)	12.821*(0.000)
Levin-Lin-Chu(2002)					
Level	12.4266 (1.000)	-0.215 (0.415)	6.746 (1.000)	-0.608 (0.272)	2.059 (0.980)
First difference	-9.162* (0.000)	-9.526*(0.000)	-9.447* (0.000)	-11.428*(0.000)	-4.712*(0.000)

Notes: The null hypothesis is that the series is a unit-root process except the Hadri (2000) test. P-values are given in parentheses.
The probabilities for the Fisher-type tests are computed using an asymptotic Chi-square distribution. All the other tests are assumed to be asymptotic normal. The lag length is selected using the Modified Schwarz Information Criteria.
* Indicates the parameters are significant at the 5% level.
**Indicates the parameters are significant at the 10% level.
[a]all of values are z(t-bar).

Source: Author, 2013

4.4.2 **Sweden – panel cointegration tests**

Once it is established that the panel unit root exists, the issue regarding the existence of a long run equilibrium relationship between the variables arises. With the provided order of integration of each variable at I (1), we use Kao (1999) and Pedroni's (1999, 2004) test to first check for panel cointegration.

Table 4-11. Kao's residual cointegration test results

	Lag [a]	t-statistic	Probability
ADF	2	-8.909*	0.0000

[a] lag selection using Parzen kernel,
*Indicate that the parameters are significant at the 5% level.

Source: Author, 2013

Using the Parzen kernel Criterion, the optimal lag length is selected. The Kao (1999) test results in Table 4-11 reveal the rejection of the null hypothesis; thus, the presence of cointegration among variables is confirmed.

Pedroni (2004) proposed that in the absence of structural breaks in the data, there are seven tests that can be used to test for panel cointegration. Prior to performing the cointegration test the Pedroni test of Eviews (6) program was used to remove the common time effects through demeaning the data.

Table 4-12. Pedroni's (2004) panel cointegration test

Alternative hypothesis: common AR coefs. (within-dimension)		
	Statistic	Prob.
Panel v-Statistic	1.555407*	0.0599
Panel rho-Statistic	0.120799	0.5481
Panel PP-Statistic	-9.240464*	0.0000
Panel ADF-Statistic	-9.235364*	0.0000
Alternative hypothesis: individual AR coefs. (between-dimension)		
	Statistic	Prob.
Group rho-Statistic	1.992913	0.9769
Group PP-Statistic	-10.42079*	0.0000
Group ADF-Statistic	-10.47549*	0.0000

Notes: The null hypothesis is that the variables are not cointegrated.
Under the null tests, all the statistics are distributed as normal (0, 1).
*Indicate that the parameters are significant at the 5% level.

Source: Author, 2013

Evidence of cointegration was revealed by five of the seven Pedroni (2004) results. Therefore, without allowing for structural breaks in the series in the Swedish sectors, it is confirmed that long run cointegration relation among the panel variables exists based on the Pedroni (2004) test.

4.4.3 **Sweden – panel Granger causality results**

To examine any causal relationship direction between the variables, the F-test is applied here. Evidence of short run Granger causality direction is provided by the significance of the first differenced variables, while the t-statistics on the one-period lagged error correction term denotes long run Granger causality. The PMG or DFE proposed by

Pesaran et al. (1999) has been used for estimation of Equations (3.21)–(3.25). We have chosen the proposed estimation method according to Hausman, and the F-test results are given below in Table 4-13.

Table 4-13. Panel short run and long run causality test results, Sweden

Dependent Variable	*Source of Causation (independent variable)*						*Estimation Method , Based on Hausman Test*
	Short Run					*Long Run*	
	ΔEG	ΔL	ΔICT	Δnon-ICT	ΔTFP	ECT	
ΔEG	-----	0.4506* (0.001)	0.9309* (0.002)	-0.0463* (0.003)	0.4751* (0.001)	-0.5197* (0.000)	DFE
ΔL	0.3660* (0.001)	-------	-0.3625 (0.103)	0.8866 (0.464)	-0.2862* (0.008)	-0.6267* (0.000)	PMG
ΔICT	0.1202* (0.008)	-0.1124* (0.003)	------	0.0094** (0.069)	-0.1181* (0.005)	-0.4129* (0.000)	DFE
Δnon-ICT	-0.2224* (0.099)	0.2296* (0.087)	0.2969 (0.467)	------	0.2281** (0.074)	-0.9132* (0.000)	DFE
ΔTFP	0.5207* (0.001)	-0.4849* (0.001)	-0.9801* (0.003)	0.0478* (0.003)	--------	-0.4857* (0.001)	DFE

Note: The reported values in parentheses are the p-values of the F-test.
*indicates significant at the 5% level, **indicates significant at the 10% level.

Source: Author, 2013

It is noticed that the estimated short run effect for the period 1990-2007 is positive and significant with respect to the ICT impact on output growth. Particularly, the implication of its magnitude is that output growth increased by 0.93 per cent with an upsurge of 1 per cent in ICT capital. We also noticed that the impact of non-ICT capital is significantly negative (-0.046). It seems that ICT, as the new modern capital, could have been successful in replacing non-ICT capital for Swedish industrial production growth. Therefore, the outcomes of the panel causality tests indicate that there is bi-directional causal relationship between ICT growth and economic growth for Swedish industries, which was shown by the study of Uysal (2010) for high income and upper-middle income countries.

With respect to Sweden's results in Table 4-13, most cases confirm that the impact of ICT on total factor productivity is negative (-0.98) and significant at the 5 per cent level. This sign is in accordance with the theoretical forecast that the impacts of ICT are predicted with a time lag in industrial levels. We have captured the same results as Lind

(2008) and Daveri (2002), which proves the trend of the expanding importance of the ICT industry, specifically since the middle 1990s for six EU countries, including Sweden, albeit the negative sign looks like the celebrated productivity paradox.

As the final note, we ought to point out that the disclosed error correction term coefficients in the last column are negative, statistically significant and half of unity indicating that any kind of change of output from the long-term balance level sources a change to the reverse direction and sluggish speed of adjusting of output to its long run trend.

Table 4-14. Panel industries causal direction in short run and long run, Sweden

Short run causality		*Long run causality*	
Direction of Causality	*Wald F-test*	*Direction of Causality*	*Wald F-test*
ΔEG ←-------→ ΔL	(0.001)* (0.001)*	EG ←-------→ L	(0.000)** (0.000)*
ΔEG ←-------→ ΔICT	(0.002)* (0.008)*	EG ←-------→ ICT	(0.000)* (0.000)*
ΔEG ←-------→ Δnon-ICT	(0.003)* (0.099)**	EG ←-------→ non-ICT	(0.000)* (0.000)*
ΔEG ←-------→ ΔTFP	(0.001)* (0.001)*	EG ←-------→ TFP	(0.000)* (0.001)*
ΔL --------→ ΔICT	(0.103) (0.003)*	L ←-------→ ICT	(0.000)* (0.000)*
ΔL --------→ Δnon-ICT	(0.464) (0.089)**	L ←-------→ non-ICT	(0.000)* (0.000)*
ΔL ←-------→ ΔTFP	(0.008)* (0.001)*	L ←-------→ TFP	(0.000)* (0.001)*
ΔICT ←-------- Δnon-ICT	(0.069)** (0.467)	ICT ←-------→ non-ICT	(0.000)* (0.000)*
ΔICT ←-------→ ΔTFP	(0.005)* (0.003)*	ICT ←-------→ TFP	(0.000)* (0.001)*
Δnon-ICT ←-------→ ΔTFP	(0.003)* (0.074)**	non-ICT ←-------→ TFP	(0.001)* (0.000)*

Note: The reported values in parentheses are the p-values of the F-test.
*indicates significant at the 5% level, **indicates significant at the 10% level.

Source: Author, 2013

The results in Table 4-14 show the short run and long run bidirectional Granger causality flows from GDP growth to the contribution of L, non-ICT, and TFP growth at the 5% and 10% significant level, respectively. There is a bidirectional long run causal flow from labour employment to contribution of ICT, non-ICT and TFP growth at the 5% significant level and unidirectional short run causality running from L to ICT and non-ICT capital. However, together, the short run labour factor growth and TFP have a significant and negative bidirectional effect.

The findings in Table 4-14 indicate that there is panel long run and short run bidirectional causality between ICT and TFP growth and non-ICT and TFP at the 5 per cent and 10 per cent significant levels. Therefore, L and ICT are negative and EG and non-ICT are positive effective components of TFP growth in Sweden. This means the results prove that ICT growth in the short run could not improve non-ICT capital but in the long run they can improve each other.

Finally, ICT is recognized as the main root of growth for Swedish sectors based on the higher positive significant coefficient of ICT (0.93 per cent) than the other input factors. We conclude that the short run results for causality are found to diminish significantly. In spite of this, the long run results are extremely significant. The long run information is in line with Dimelis and Papaioannou's (2011) findings for a panel of EU and US developed countries.

4.4.4 **Sweden – long run relationship by System GMM**

We use a reasonable approach by selecting one lag of the dependent and interaction of binary variables (ICT_non-ICT), as instruments (IVs) in the System GMM regressions. We employ Hansen's J test to verify whether the instruments used are valid. If it is valid, then we will not be able to reject the null hypothesis that the instrumental variables are uncorrelated with the residuals. The results of the System GMM are illustrated in Table 4-15 in one-step and two-step.

System GMM regressions are conducted based on equation (3.16), after using the heteroscedasticity robust one-step estimator in columns (1) and (2), and the two-step in column (3) and (4). In column (1) and (2), the regression outputs are demonstrated for 1990-2007 after including the interaction terms between binary variables and ICT capital. Moreover, in these columns, we would like to examine the complementarity hypothesis between ICT and non-ICT capital by implementing their interaction term (ICT_non-ICT) as an individual regressor.

Table 4-15. Long run panel data estimators for industries, Sweden

Independent Variables	*Dependent variable: EG*			
	SystemGMM Estimates, One-step		*System GMM Estimates, Two-step*	
	(1)	*(2)*	*(3)*	*(4)*
L	0.870* (0.000)	0.899* (0.000)	0.873* (0.000)	0.897* (0.000)
ICT	3.013* (0.000)	1.405* (0.005)	3.565* (0.000)	1.472* (0.000)
Non-ICT	0.743* (0.009)	0.364 (0.160)	0.853* (0.000)	0.350* (0.000)
TFP	0.957* (0.000)	0.935* (0.000)	0.963* (0.000)	0.931* (0.000)
ICT_PROD	0.715 (0.459)		0.583 (0.324)	
ICT_USE	-0.789 (0.269)		-1.229** (0.091)	
ICT_nonICT	-0.433* (0.001)		-0.495* (0.000)	
Constant	0.294** (0.082)	0.860* (0.001)	0.149 (0.335)	0.819* (0.000)
Obs	294	294	294	294
Industries	21	21	21	21
Wald test	15635.21	938.94	83141.30	58612.03
Sargan test (p-value)a	0.000	0.000	0.000	0.000
Hansen test (p-value)b	1.000	1.000	1.000	1.000
Serial correlation test AR(2) (p-value)c	0.106	0.666	0.206	0.944
Serial correlation test AR(3) (p-value)d	0.134	0.099	0.224	0.169

a. Sargan test is evaluating overidentifying restrictions in Ivs. The null hypothesis is that the instruments used in the regression are valid.
b. Hansen test is evaluating overidentifying restrictions in GMM. The null hypothesis is that the instruments used in the regression are exogenous.
c. d. The null hypothesis is that the error in the first-difference regression exhibit no first or second order serial correlation.
The values in parentheses denote the significance level for rejection.
*Indicate that the parameters are significant at the 5% level.
**Indicate that the parameters are significant at the 10% level.

Source: Author, 2013

From the revealed estimations of Table 4-15 it appears evident that the effect of employment, ICT, and non-ICT capitals on the Sweden industrial growth was extremely positive and significant during the 17 years, whereas TFP might make a positive and significant contribution (0.963 per cent) to output growth.

It is clear from the PMG estimators finding, that the overall ICT growth contribution is positive and significant. Therefore, our estimated results from PMG and GMM have jointly proved that ICT is the main reason of growth of Swedish industries during the period due to the considerable differences in the ICT coefficient to others.

However, the System GMM results have supplemented these positive effects, which are more rooted in ICT-using'industries because the effects of ICT-producing industries are insignificant to value added growth. ICT-producing industries is introduced as similar to Japan whereas, “food, beverages and tobacco”, ”textiles, leather and footwear”, “wood and of wood and cork”, “chemical, rubber, plastics and fuel”, “basic metals and fabricated metal”, “electricity, gas and water supply”, “transport and storage and communication”, “post and telecommunications”, “finance, insurance, real estate and business services” and “community social and personal services” industries are introduced as ICT-using sectors. The results of columns (1) and (3) show that considerable negative complementary impacts can be found between ICT and non-ICT capital (interaction term ICT_non-ICT).

On the other hand, the record leads to these columns indicate that the productivity effects of ICT are significantly bigger in the ICT-using industries. Coupled with the outcomes of previous tables, we can confirm that the beneficial impacts of ICT are mainly concentrated in the degree of penetration of ICT between industries, such as the research results of Jorgenson et al. (2003); Oh, Heshmati, and Lööf (2009b), Van Ark and Piatkowski (2004).

4.4.5 Justification of significant effects of ICT on TFP and GDP growth in Sweden

Based on the high GDP share of the ICT-producing sector (20.41 per cent), which is "Electrical and optical equipment” industries, as illustrated in Figure 4-8, the significant effects of ICT on TFP and value added growth can be explained. In Sweden, there was around a twelve-fold decrease in the contribution of “Electrical and optical equipment” from 24.53 to 2.48 percentage points between 1990 and 2007. However, the average contribution of these industries increased to 20.41 percentage points, which is a considerable share of Sweden’s output growth rate. This research denotes that, from this viewpoint, the ICT industry has performed a more significant role in Sweden than others from the middlle of 1990s.

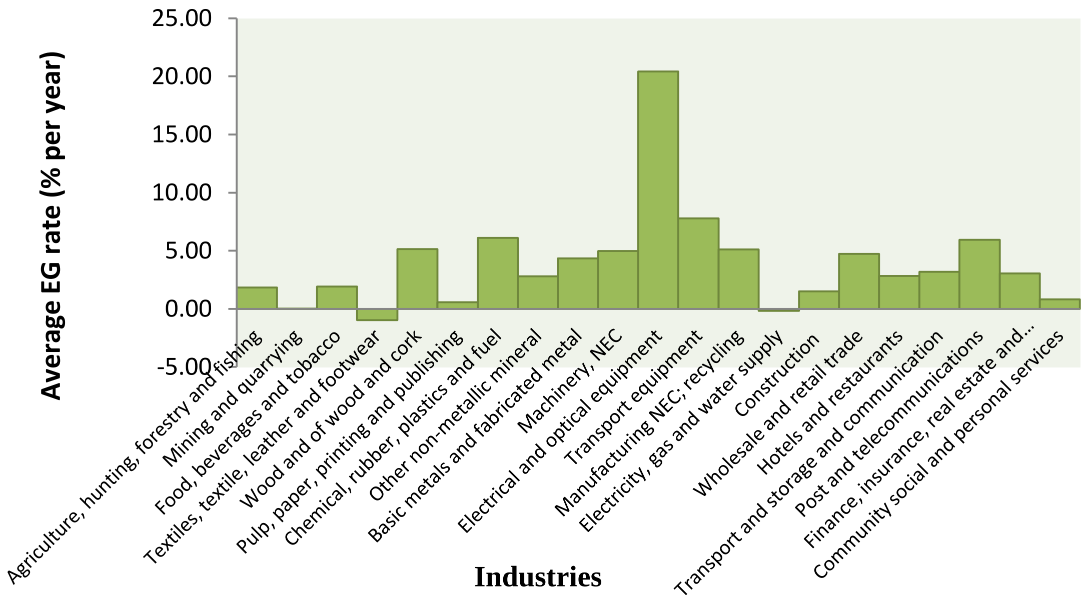

Figure 4-8. Average growth rate of value added for each industry, Sweden
Source: Author Analysis, 2013

It can be concluded that Sweden is unambiguously much more influenced by ICT-production than others, thus Sweden achieved a high growth rate of GDP due to the heavy investment in "Electrical and optical equipment” sectors in recent decades. Moreover, according to OECD (2009) electronic manufacture and post and telecommunication were the exclusive industries with substantial effects.

On the other hand, the highest contributor to value added growth between 1990 and 2011 was growth of TFP. Therefore, ICT has a spillover effect through TFP growth for Swedish industries because of the significant impact of ICT on TFP. Lindström (2003) attributed the substantial TFP growth in the business sector during the period 1993-1999 to the ICT-producing sector, which has shown causality results in the previous sections.

Indeed the negative coefficient of ICT on TFP illustrated the existing time lag in the appearance of the significant spillover effects of ICT on growth.

Generally, one of the most important explanations for the significant effect of ICT could be the spillover effect of ICT via the largest contribution of TFP in Sweden among other countries, whereas the contribution of other EU nations was even more affordable but amounted to less than Sweden. The EU, non-ICT relevant sources of growth are the key drivers of productivity differentials between individual countries (Timmer & Ark, 2005). In the Swedish background, Lind (2008) was on record that the contribution of ICT-production to labour productivity growth in the business sector increased from 28 to 60 per cent between 1994 and 1997, and 1998 and 2001. As reported by Lind (2008), labour productivity growth in the Swedish producing industry reached the mean in OECD countries between 1960 and 2001.

An additional part is associated with computer and relevant services, the industry that represents much of the production of software. This industry is specifically massive in Sweden (OECD, 2003). In both Sweden and Finland, the service-related ICT-industries improved their portion of the business sector value added in the previous 30 years. The portion of hours performed in ICT services in 2004 was somehow larger in Sweden than in Finland. Electrical power engineering and post and telecommunication were the sectors with substantial effects.

4.5 Australia – Growth Decomposition

Australia is an example of a country with strong TFP growth in ICT-using industries but no important ICT-producing sector. Because of that, Australia showed quite strong growth in ICT investment in the 1990s and it achieved a large proportion of growth between 1990 and 2007 (0.76 per cent). Previous studies manifested that finance and manufacturing, and insurance were specifically outstanding in the consumption of ICTs (Gretton et al., 2002).

Table 4-16. Australia growth decomposition

Variable	Obs	Mean	Std. Dev.	Min	Max
EG(%)	378	2.325132	5.695726	-27.12	25.56
L(%)	378	0.021085	4.842255	-23.29	31.48
ICT(%)	378	0.755714	0.726251	-0.64	4.75
non-ICT(%)	378	0.823995	1.171329	-2.04	9.6
TFP(%)	378	0.587646	6.572104	-41.98	28.27

Source:EU KLEMS Database, 1990-2007

Table 4-16 illustrates that non-ICT is considered as a main contributor to growth with 0.82 per cent contribution and that ICT is the second component of growth with an average 0.76 per cent contribution to value added growth. The national accounts show that real ICT contribution grew from around -0.64 per cent of total value added in 1990-2007 to around 4.75 per cent. Therefore, based on the small contribution of labour employment (0.02 per cent) to growth, we can claim that Australian industries are not labour based.

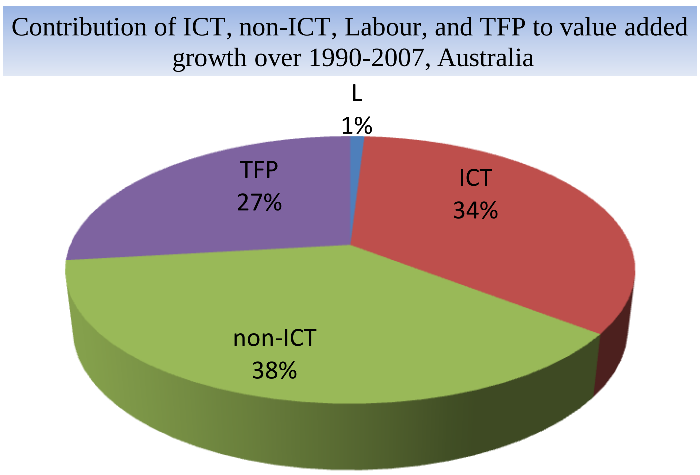

Figure 4-9. Contribution of ICT, non-ICT, Labour, and TFP to value added
Source: EU KLEMS Database, 1990-2007

Figure 4-9 shows a 34 per cent contribution of ICT to annual output growth in Australia. This is because of the quick diffusion of ICTs among firms in the 1990s to match the prompt growth in investment and employment. The reasons presented in the literature include that, in 1993-94, around fifty per cent of companies in a great number of sectors applied computers and around thirty per cent had Internet accessibility. By 2000-05, these proportions grew to nearly eighty-five and seventy per cent respectively (Gretton et al., 2002). At that time, Australia experienced a 0.27 per cent rise in TFP by the ICT spillover effect through wide ICT diffusion.

4.5.1 Australia – panel unit root tests

Australia's outputs of the panel unit root tests are shown in Table 4-17. The test statistics for the levels of variables are statistically insignificant besides the Levin-Lin-Chu (2002) test for TFP contribution. Considered as a whole, the results reported that all five variables are panel non-stationary. When we implement the panel unit root tests to the first difference of the five variables, almost all tests reject the null hypothesis for all the variables excluding the Hadri (2000) test, since, within this test, the null is checked and the panels are stationary.

Table 4-17. Panel unit root tests, Australia

Method	EG	L	ICT	Non-ICT	TFP
Breitung(2000)					
Level	-0.697(0.243)	-0.912(0.181)	-0.946(0.172)	-1.179(0.119)	-1.117(0.132)
First difference	2.068*(0.019)	1.508**(0.066)	-3.866*(0.000)	-3.113*(0.001)	-2.453*(0.007)
Hadri(2000)					
Level	2.117*(0.017)	3.719*(0.000)	6.786*(0.000)	5.750*(0.000)	1.604**(0.054)
First difference	-0.483(0.685)	0.428(0.335)	-1.843(0.967)	-0.518 (0.698)	-0.923(0.822)
Pesaran (2003)					
Level	1.186^{a}(0.882)	2.645^{a}(0.996)	0.033 ^{a}(0.513)	-0.735^{a}(0.231)	-0.315 ^{a}(0.376)
First difference	-1.815 ^{a**}(0.035)	-1.598^{a*} (0.055)	-3.338^{a*}(0.000)	-6.305^{a*}(0.000	-3.813 ^{a*}(0.000)
Maddala & Wu(1999),Fisher					
Level	-1.360(0.913)	-0.849(0.802)	0.165(0.434)	-0.254(0.600)	-0.4069(0.658)
First difference	5.153*(0.000)	4.335(0.000)	4.202*(0.000)	4.958*(0.000)	6.395*(0.000)
Levin-Lin-Chu(2002)					
Level	-1.002(0.158)	0.672(0.749)	1.009(0.844)	0.715(0.762)	2.009**(0.022)
First difference	-4.479*(0.000)	-4.977*(0.000)	-6.109*(0.000)	-6.021*(0.000)	11.986*(0.000)

Notes: The null hypothesis is that the series is a unit-root process except the Hadri (2000) test. P-values are given in parentheses.
Probabilities for the Fisher-type tests are computed using an asymptotic Chi-square distribution. All the other tests are assumed to be asymptotic normal. The lag length is selected using the Modified Schwarz Information Criteria.
* Indicates the parameters are significant at the 5% level.
**Indicates the parameters are significant at the 10% level.
[a]all of values are z(t-bar).

Source: Author, 2013

A large scale Monte Carlo simulation study by Hlouskova and Wagner (2006) discovered that the Breitung (2000) panel unit root test usually achieved the highest strength and the smallest dimension distortions compared to the other panel unit root tests. Therefore, in general, it can be assumed to determine that all the variables consist of a panel unit root.

4.5.2 Australia – panel cointegration tests

As it has been established that a unit root exists in all five variables, we proceed by testing as to whether there is an existence of a long run relationship between EG, L, ICT, non-ICT, and TFP using the Kao (1999) and Pedroni (2004) heterogeneous panel cointegration test. Under the assumption of alternative dependent variables, the results are reported in Tables 4-18 and 4-19.

Table 4-18. Kao's residual cointegration test results

	Lag [a]	t-statistic	Probability
ADF	3	-12.45962*	0.0000

Note: Null Hypothesis: No cointegration,
[a] lag selection using Parzen kernel,
*Indicate that the parameters are significant at the 5% level.

Source: Author, 2013

By using the Parzen Kernel Criterion, the optimal lag length is selected. Kao's (1999) test results in Table 4-19 rejected the null hypothesis; thus, the existence of cointegration among the variables is confirmed.

Monte Carlo simulations using the finite sample distribution for the seven statistics are tabulated in Pedroni (2004). If the critical values in Pedroni (2004) are exceeded by the test statistic, then no cointegration null hypothesis is rejected, which implies that a long run relationship exists between variables.

Table 4-19. Pedroni's (2004) panel cointegration test

Alternative hypothesis: common AR coefs. (within-dimension)		
	Statistic	Prob.
Panel v-Statistic	3.483891*	0.0002
Panel rho-Statistic	-1.029702	0.1516
Panel PP-Statistic	-5.677250*	0.0000
Panel ADF-Statistic	-5.239257*	0.0000
Alternative hypothesis: individual AR coefs. (between-dimension)		
	Statistic	Prob.
Group rho-Statistic	0.369409	0.6441
Group PP-Statistic	-7.541261*	0.0000
Group ADF-Statistic	-7.413333*	0.0000

Notes: The null hypothesis is that the variables are not cointegrated.
Under the null tests, all the statistics are distributed as normal (0, 1).
*Indicate that the parameters are significant at the 5% level.

Source: Author, 2013

There are four panel cointegration tests (between dimensions) among the suggested seven tests by Pedroni (1999) while the others comprise of mean panel cointegration tests (between dimensions), which are quite general in nature as they allow heterogeneous coefficients. When the Pedroni (2004) test statistics have a large negative value, the null hypothesis of no cointegration is rejected by the Pedroni (2004) test except for the group rho-Statistic, which does not reject the null of no cointegration when it has a large positive value.

4.5.3 **Australia – panel Granger causality results**

To demonstrate the existence of a long run relationship between output growth, labour, ICT, non-ICT and TFP contribution, as shown in Table 4-20, we analyse the direction of causality between the variables in a panel framework. We designate a model with a dynamic error correction representation.

The Granger causality test is based on the regressions (3.21) - (3.25) in Chapter 3. Δ denotes the first difference of the variable and the significance coefficient reveals the short run causality while the coefficient of the Error Correction Terms (ECT) shows the long run causality. The optimum lag size was preferred, automatically choosing the Schwarz information criteria.

Table 4-20. Panel causality test results, Australia

Dependent Variable	*Source of Causation (independent variable)*						Estimation Method , Based on Hausman Test
	Short Run					*Long Run*	
	ΔEG	ΔL	ΔICT	Δnon-ICT	ΔTFP	ECT	
ΔEG	-----	0.2008** (0.055)	0.4136 * (0.006)	0.1870 (0.166)	0 1870** (0.080)	-0.7828 * (0.000)	PMG
ΔL	0.1906** (0.072)	-------	-0.4782* (0.002)	-0.1583 (0.230)	-0.1803** (0.097)	-0.7978* (0.000)	PMG
ΔICT	-0.0499** (0.083)	0.0528** (0.066)	------	0.0240 (0.523)	0.0558** (0.052)	-0.9663* (0.000)	DFE
Δnon-ICT	-0.1533* (0.047)	-0.1582* (0.036)	-0.0365 (0.761)	-------	-0.1495** (0.053)	-0.5520* (0.000)	PMG
ΔTFP	0.1869** (0.078)	-0.1894** (0.076)	-0.4754* (0.002)	-0.1515 (0.246)	--------	-0. 8262* (0.000)	PMG

Note: The reported values in parentheses are the p-values of the F-test.
*indicates significant at 5% level, **indicates significant at 10% level.

Source: Author, 2013

The panel Granger causality outcome is revealed in Table 4-20. A 1 per cent improvement in ICT contribution enhances GDP by 0.41 per cent, when a 1 per cent increase in L, non-ICT, and TFP increases value added growth by 0.20 per cent, 0.19 per cent, and 0.19 per cent, respectively.

Table 4-21. Panel industries direction of causality in short run and long run, Australia

Short Run causality		*Long Run causality*	
Direction of Causality	*Wald F-test*	*Direction of Causality*	*Wald F-test*
ΔEG ←-------→ ΔL	(0.055)** (0.072)**	EG ←-------→ L	(0.000)* (0.000)*
ΔEG ←-------→ ΔICT	(0.006)* (0.083)*	EG ←-------→ ICT	(0.000)* (0.000)*
ΔEG ---------→ Δnon-ICT	(0.166) (0.047)*	EG ←-------→ non-ICT	(0.000)* (0.000)*
ΔEG ←-------→ ΔTFP	(0.080)** (0.078)**	EG ←-------→ TFP	(0.000)** (0.001)*
ΔL ←-------→ ΔICT	(0.002)* (0.066)**	L ←-------→ ICT	(0.000)* (0.000)*
ΔL ---------→ Δnon-ICT	(0.230) (0.036)*	L ←-------→ non-ICT	(0.000)* (0.000)*
ΔL ←-------→ ΔTFP	(0.097)* (0.076)*	L ←-------→ TFP	(0.000)* (0.000)*
ΔICT No Causality Δnon-ICT	(0.523) (0.761)	ICT ←-------→ non-ICT	(0.000)* (0.000)*
ΔICT ←-------→ ΔTFP	(0.052)** (0.002)*	ICT ←-------→ TFP	(0.000)* (0.000)*
Δnon-ICT ←--------- ΔTFP	(0.246) (0.053)**	non-ICT ←-------→ TFP	(0.000)* (0.000)*

Note: The reported values in parentheses are the p-values of the F-test.
*indicates significant at the 5% level, **indicates significant at the 10% level.

Source: Author, 2013

The important point here is that non-ICT capital has become insignificant to GDP growth in the short run whereas ICT has the most significant positive effect on output growth similar to the results for Sweden. The findings in Table 4-21 indicate that there is unidirectional short run panel Granger causality running from EG, labour capital and TFP to non-ICT. This means that non-ICT in Australia might not be the determining factor of output and TFP growth in the short run. There is a bidirectional long run Granger causality between value added growth and the contribution of ICT, non-ICT, L, and TFP pairwise. Therefore, we can identify ICT as the major source of growth in the Australian sectors over 1990-2007 (0. 41 per cent). Furthermore, ICT is associated negatively and significantly to TFP in the long run and also the short run. Therefore, we can conclude that the evidence is in line with the theoretical expectation that the impacts of ICT on TFP are expected with a time lag in industrial level to significant effects of ICT on TFP in the long run. Importantly, these results are in line with the firm level econometric analysis of Gretton et al. (2004), which controls for other effects and shows positive connections between ICT use and productivity growth in Australian industries. However, this result is in contrast to the findings of Colecchia and Schreyer (2002) about the increasing contribution of ICT to productivity during the second half of the 1990s.

4.5.4 **Australia – long run relationship by System GMM**

To estimate equation (15), System GMM is applied, which controls the problem of endogeneity and the serial correlation of regressors. In Table 4-22 below, the estimated results are specified. Regarding the Australian industries, the System GMM estimates show that at the 5 per cent significant level (0.98 per cent, 0.95 per cent) the output elasticities of labour and ICT capital are significant and highly positive. Overall, there is a positive and significant ICT growth contribution in both the one-step and two-step results (columns 1 and 3). These results are in line with the long run PMG estimators and it is suggested that an important role can be played by ICT in enhancing the economic growth of Australia due to its faster capital accumulation.

It is indicated by the estimates of column 1 in the ICT-producing industries that the returns to ICT were positive and significantly higher (0.176 per cent), unlike the case for ICT-using industries (-0.063 per cent).

Table 4-22. Long run panel data estimators for industries, Australia

Independent Variables	*Dependent variable:EG*			
	System GMM Estimates, One-step		*System GMM Estimates, Two-step*	
	(1)	*(2)*	*(3)*	*(4)*
L	0.988* (0.000)	0.988* (0.000)	0.984* (0.000)	0.990* (0.000)
ICT	1.005* (0.000)	0.989* (0.000)	0.955* (0.003)	1.055* (0.000)
Non-ICT	0.981* (0.000)	0.987* (0.000)	0.877* (0.000)	0.972* (0.000)
TFP	0.993* (0.000)	0.993* (0.000)	0.991* (0.000)	0.993* (0.000)
ICT_PROD	0.176** (0.073)	-------	0.265 (0.446)	-------
ICT_USE	-0.063 (0.202)	------	0.025 (0.879)	-------
ICT_non-ICT	0.023 (0.458)	------	0.092 (0.599)	-------
Constant	0.147* (0.000)	0.149* (0.000)	0.271* (0.027)	0.135* (0.016)
Obs	336	336	336	336
Industries	21	21	21	21
Wald test	55002.85	50051.25	212275.78	448325.01
Sargan test(p-value)a	0.000	0.000	0.000	0.000
Hansen test (p-value)b	1.000	0.538	1.000	0.538
Serial correlation test AR(2) (p-value)c	0.851	0.901	0.852	0.918
Serial correlation test AR(3) (p-value)d	0.290	0.229	0.238	0.208

a.Sargan test is evaluating the overidentifying restrictions in Ivs. The null hypothesis is that the instruments used in the regression are valid.
b. Hansen test is evaluating the overidentifying restrictions in GMM. The null hypothesis is that the instruments used in the regression are exogenous.
c. d. The null hypothesis is that the error in the first-difference regression exhibit no first or second order serial correlation.
The values in parentheses denote the significance level for rejection.
*Indicate that the parameters are significant at the 5% level.
**Indicate that the parameters are significant at the 10% level.

Source: Author, 2013

The evidence found is in line with the study of O'Mahony (2005) and Van Ark et al. (2003) who argued that there is still a solid prospective in the EU service industries that make intensive use of ICT to exploit growth benefits. Therefore, the Australian economy can capture a higher contribution of ICT and growth in GDP through the reinforcement of intensive ICT-using industries.

Furthermore, based on the results in column 3, neither ICT-producing nor ICT-using industries have an insignificant effect on growth. Specifically, the estimates derived give an indication that the contribution of ICT was 0.27 per cent more in ICT-producing and 0.03% more in ICT-using industries relative to the remaining industries. The impact of ICT on growth in ICT-using and producing industries was quite sizable and significantly higher (interaction terms of ICT_PROD and ICT_USE, respectively), as per the results reported in the third column of Table 4-22. The evidence in line with this discussion, that the productivity advantage of the Australian economy has been linked to the sectors that are either heavy users of ICT or producers of ICT, is quite substantial. Moreover, it appears that compared to the ICT-using industries, higher returns are enjoyed by ICT-producing industries. Thus, ICT-producing industries have significantly higher productivity effects of ICT. In combination with the previous discussion results, it can be concluded that the beneficial effects of ICTs are mostly focussed on ICT intensive industries (Draca, Sadun, & Reenen, 2006; Pilat, 2004; Shao & Shu, 2004).

The Hansen test accepts the null hypothesis, which states the validity of the instruments used in the regressions. Moreover, the null hypothesis is accepted by the test that examines the second and third-order serial correlation, which means that there is no evidence of second and third-order serial correlation in the error term. Additional support is granted to the estimates reported in Table 4-22 by the results of both tests.

4.5.5 Justification of significant effects of ICT on TFP and GDP growth in Australia

"Mining and quarrying", "Food, beverages and tobacco", "Transport equipment", "Manufacturing NEC; recycling", "Electricity, gas and water supply", "Wholesale and retail trade", "Post and telecommunications" and "Transport and storage and communication" are considered as ICT-using industries and "Electrical and optical equipment" as a ICT-producing industry in Australia. The highest share of GDP growth is belonging to "Post and telecommunications" and "Transport, storage and communication" via 7.12 and 4.41 percentage point average growth of GDP growth per year, respectively (see Figure 4-10).

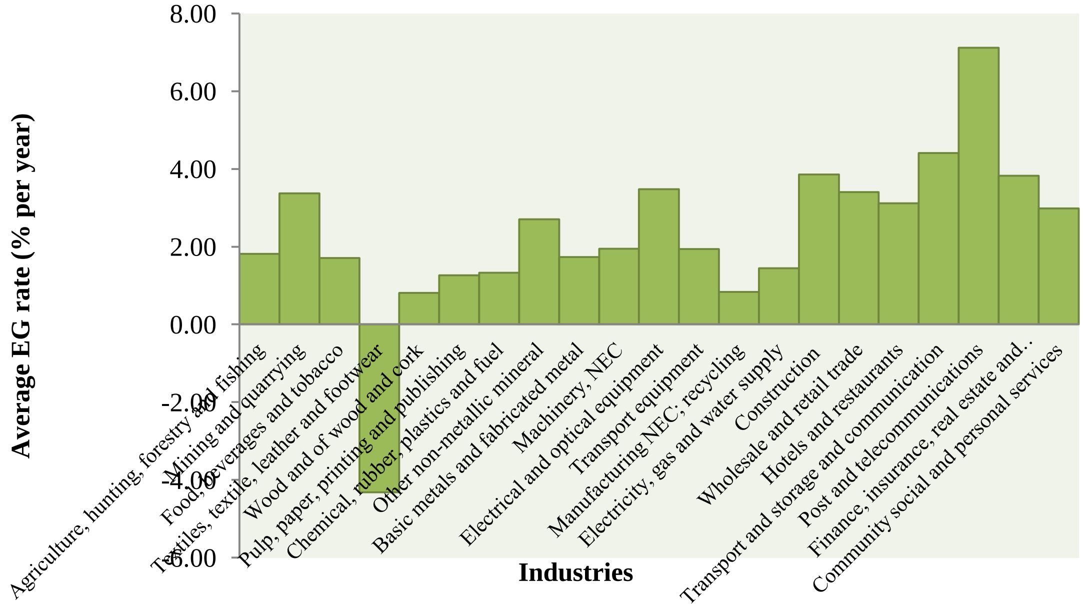

Figure 4-10. Average growth rate of value added for each industry, Australia
Source: Author Analysis, 2013

The two industries mentioned earlier, which are both ICT-using industries, contribute significantly to the economic growth of Australia, therefore, if Australia relies on improvement in ICT-using it could increase the growth rate of value added in years to come.

Australia, with an average 3.47 per cent share of ICT-producing sector from GDP growth has the smallest portion of ICT-producing industries among five countries. The largest ICT manufacturing sectors are Ireland and Finland, trailed by Korea. In contrast, Australia and New Zealand only have a small sector, which produces manufactured ICT goods (Margaret & Ray, 2003). According to this study, for the period under consideration, for the countries to benefit from effects of ICT on growth, the lack of a large ICT-producing industry is not necessarily an impediment. Australia is a prime example in that although it only has a small ICT-producing sector it has significantly benefited from ICT capital services.

ICT and non-ICT capital with 38 per cent and 34 per cent, respectively, are the highest contributors to value added growth over 1990-2011 in Australia. However, from the large magnitude coefficient of ICT in comparison to non-ICT in the GMM results, ICT could be a kind of economic growth source in Australia via the high penetration of ICT.

Furthermore, one of the reasons for the high penetration of ICT in Australia is from the establishment of an organisation called Australia's Information and Communications Technology Research Centre of Excellence (NICTA) in 2002, which was built to strengthen investment and build capacity in communications technology and strategic information research. There could be an improvement in the ability of Australia to fully capture the transformational and productivity benefits brought forth by the communication and information technology.

“NICTA” will help in the transformation of the ICT sector of Australia and the traditionally strong competitiveness of the sector will be strengthened, such as primary industries, entertainment, financial services, health, education and resources. NICTA is an independent company, which is a not-for-profit and is limited by guarantee.

Its four founding member organisations are the "ACT Government", “Australian National University", "University of New South Wales", and “NSW Government". The

ICT effect on GDP over 1990-2001 was 0.99, which changed to 1.06 during 2001-2011; therefore the performance of the NICTA organization is considerable in stimulating the penetration of ICT after 2002 (OECD, 2002).

The spillover effects of ICT with time lagging through increasing TFP have stimulated the direct significant effects of ICT on growth. On the other hand, the contribution of ICT capital to GDP growth was the largest in Australia, which is 0.75 per cent on average over the years 1990-2011; followed by Finland among the other five countries in this research.

4.6 Finland – Growth Decomposition

Recently, in terms of GDP growth and labour productivity contribution, the leading industry in Finland is the communication and information technology sector. Labour productivity in Finland, which is measured by means of the value added per hour worked in four manufacturing industries – basic metals, telecommunications equipment, pulp and paper, and wood and wood products – is the highest relative to the other EU-15 member countries in 2001.

Real gross valued added measures the output while over the entire period, 90% of output growth arises from growth in TFP, particularly labour productivity. In the two decades, relative contribution of TFP was at its highest in Finland. As many industrial nations have suffered slowdown in the productivity recently, Finland has done better inasmuch as it has not been affected by a productivity slowdown to the same extent as other nations. This is mainly down to its success as an ICT-producer.

In the early 1990s, severe depression hit the Finnish economy. In the non-residential market sector, there was a 10 per cent fall in the volume of gross value between 1990 and 1992. However, the recovery was quick, and, by the looks of it, there was no major difference in the period 1990 to 2005 and the preceding period. However, there was another sharp decline in GDP growth in Finland.

In the twentieth-century, the Finnish economy went through a transformation from a country dependant mostly on natural resources into a modern industrial society with cutting edge telecommunication manufacturing in the world with Nokia being the flagship of Finnish telecommunications (Häikiö, 2007). Moreover, in the adoption of the telephone, Finland was one of the leading countries. In December 1877, only 18 months after the United States obtained the patent for the telephone, in Helsinki, the first line for a telephone was built (Turpeinen & Yau, 1981).

The living standard of the United States back in 1950, as measured by using gross domestic product (GDP) per capita, was more than double that of the Finnish equivalent. By 2003, the ratio reached three-quarters (Ojala, Eloranta, & Jalava, 2006). From 1990 to 1993 real GDP dropped by 11 per cent due to the recession in the early 1990s, which became the largest peacetime hurdle.

Table 4-23. Finland growth decomposition

Variable	Obs	Mean	Std. Dev.	Min	Max
EG(%)	378	2.426243	8.440859	-35.75	35.36
L(%)	378	-0.88093	4.367566	-25.01	10.71
ICT(%)	378	0.364497	0.484631	-0.4	3.27
non-ICT(%)	378	0.340132	1.125556	-1.97	6.63
TFP(%)	378	2.318651	7.034464	-39.12	27.11

Source: EU KLEMS Database, 1990-2007

According to the World Bank Indicator dataset, in 1990, ICTs contribution to the overall GDP growth was 0.20 percentage points and in 2011 it was 0.86 percentage points. The major contribution resulted from the enhancement of TFP in ICT-producing, which is in terms of the manufacturing of ICT tools (electrical and optical equipment). The contribution of TFP in 1990 was -0.18 percentage points increasing to 0.89 percentage points in 2011. Based on Table 4-23, the average contributions of ICT capital were about 0.36 percentage points during 1990-2011. From the illustrated Table above and previous researchers over the period, the standard of living has increased (EG growth: 2.42 per cent) while there has been a decline in the number of hours worked per capita (Labour:-0.88 per cent). This might be due to the labour productivity growth and breakthrough of TFP. We have observed this concept in Figure 4-11 by illustrating the 59 per cent contribution of TFP to GDP growth, which is higher than the others.

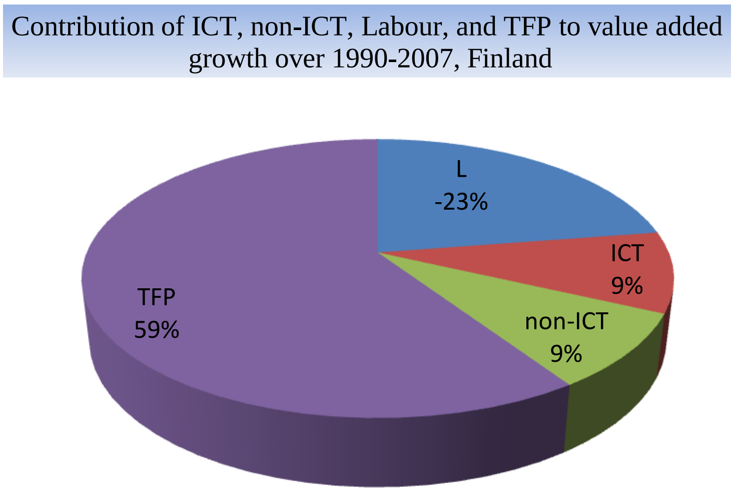

Figure 4-11. Contribution of ICT, non-ICT, Labour, and TFP to value added growth
Source: EU KLEMS Database, 1990-2007

Since the labour contribution growth was negative at -23 per cent and the ICT contribution was still low, only 9 per cent, high growth in TFP and EG has been observed. Thus, the pace at which Finland adopted telecommunications technology cannot be seen in terms of the utilisation of information technology. Although, recently, Finland has been regarded as one of the leading producers of information technology, in the ICT development index, it ranks fifth in the world (ITU, 2010).

In the world market, the telecommunications manufacturing industry of Finland was quite competitive with about 35 per cent of the global mobile phone market share dominated by Nokia. There is a special relevance in a country like Finland due to the benefits it has reaped from Nokia – the case in point is a successful production of a new technology, but, in other industries, much improvement is needed in the use of new technology for the process of production. Moreover, it has an impact on growth via the effect of total factor productivity (TFP) gains induced by rapid technological advances in the ICT-producing industries (Jalava & Pohjola, 2002).

4.6.1 **Finland – panel unit root tests**

In this study, the annual data used for 21 Finnish industries cover the period from 1990 to 2007. To avoid the possibility of spurious regression, there is a need for the examination of the properties of the variables. To provide a robust and sensitive analysis, a broad array of panel unit-root tests is employed including the Breitung (2000) test, Levin et al. test (2002, LLC), Hardi test (2000), Fisher-type ADF test, Maddala & Wu (1999) and Pesaran et al. test (PCADF, 2003). The null hypotheses of all the tests, which reveal that the panel series does not have stationary behaviour at the first difference, are rejected, except for Hardi (2000).

Table 4-24. Finland panel unit root tests

Method	EG	L	ICT	Non-ICT	TFP
Breitung(2000)					
Level	-1.549**(0.061)	-0.348(0.219)	-0.877(0.190)	-0.489 (0.313)	-0.642(0.261)
First difference	-3.803*(0.000)	-10.444*(0.000)	-5.980*(0.000)	-3.550(0.000)	-9.576*(0.000)
Hadri(2000)					
Level	2.682*(0.004)	5.340*(0.000)	4.984*(0.000)	2.540*(0.006)	1.951*(0.026)
First difference	-0.945 (0.828)	-2.289(0.989)	-1.569 (0.941)	0.696(0.243)	-0.908(0.818)
Pesaran (2003)					
Level	-0.357[a](0.361)	-0.727[a](0.234)	-0.226[a](0.411)	0.795[a] (0.787)	0.307[a](0.620)
First difference	-4.474[a]*(0.000)	-2.136[a]*(0.016)	-2.450[a]*(0.007)	-1.572[a]*(0.058)	-3.082[a]*(0.001)
Maddala &Wu (1999)Fisher					
Level	2.743*(0.003)	-0.108(0.543)	-1.461(0.928)	1.314**(0.094)	0.358(0.360)
First difference	12.286*(0.000)	2.470*(0.007)	2.759*(0.003)	5.881*(0.000)	4.962*(0.000)
Levin-Lin-hu(2002)					
Level	2.359(0.991)	-0.347(0.364)	-0.424(0.336)	-1.236(0.108)	0.553(0.709)
First difference	-8.624*(0.000)	-1.651*(0.049)	-2.478*(0.007)	-5.619*(0.000)	-1.433**(0.076)

Notes: The null hypothesis is that the series is a unit-root process except the Hadri (2000) test.
P-values are given in parentheses.
Probabilities for the Fisher-type tests are computed using an asymptotic Chi-square distribution. All the other tests are assumed to be asymptotic normal. The lag length is selected using the Modified Schwarz Information Criteria.
* Indicates the parameters are significant at the 5% level.
**Indicates the parameters are significant at the 10% level.
[a]all of values are z(t-bar).

Source: Author, 2013

The test results are reported in Table 4-24, the statistics significantly confirm that the level values of all series are non-stationary and that all the variables are stationary at the 5 per cent significant level of the first difference, that is, all variables are I(1).

4.6.2 **Finland – panel cointegration tests**

The examination of the results for the panel cointegration tests is needed to determine if the regressions are actually spurious. To provide a robust and sensitive analysis, two sets of cointegration test techniques are used. Kao (1999) provided the first set of tests, which is the Augmented Dickey-Fuller (ADF) and generalisation of the Dickey-Fuller (DF) tests in the context of panel data. Pedroni (2004) provided the second set of tests.

Table 4-25. Kao's residual cointegration test results

	Lag [a]	t-statistic	Probability
ADF	3	-12.45962*	0.0000

Note: Null Hypothesis: No cointegration,
[a] lag selection using Parzen kernel,
*Indicate that the parameters are significant at the 5% level.

Source: Author, 2013

Table 4-26. Pedroni's (2004) residual cointegration test results

Alternative hypothesis: common AR coefs. (within-dimension)		
	Statistic	Prob.
Panel v-Statistic	3.483891*	0.0002
Panel rho-Statistic	-1.029702	0.1516
Panel PP-Statistic	-5.677250*	0.0000
Panel ADF-Statistic	-5.239257*	0.0000
Alternative hypothesis: individual AR coefs. (between-dimension)		
	Statistic	Prob.
Group rho-Statistic	0.369409	0.6441
Group PP-Statistic	-7.541261*	0.0000
Group ADF-Statistic	-7.413333*	0.0000

Notes: The null hypothesis is that the variables are not cointegrated.
Under the null tests, all the statistics are distributed as normal (0, 1).
*Indicate that the parameters are significant at the 5% level.

Source: Author, 2013

The null hypothesis of no cointegration is involved in all the tests while using the residuals derived from a panel regression to construct the test statistics and distribution determinants. Asymptotic distribution is found in all the test statistics after appropriate standardisation. Table 4-26 presents the results of the panel cointegration tests proposed by Pedroni (1999, 2004). His tests can be classified into two categories. The first set is similar to the tests illustrated above and involves averaging the test statistics for cointegration in time series across sections. For the second set, averaging is done in pieces so that the limiting distributions are based on the limits of piecewise numerator and denominator terms. As shown in Table 4-26, the Pedroni (2004) heterogeneous panel statistics reject the null hypothesis of no cointegration when they have large positive or negative values with the exception for the panel rho-statistic and group rho-statistic tests, which, at the 5 per cent significance level, do not reject the null hypothesis of cointegration when it has a small positive or negative value. It is indicated in the results that the majority of the particular tests reject the null hypothesis of no cointegration for the Finnish variables. Thus, the estimation of a long run relationship between the explanatory and dependent variables is possible. The residual panel cointegration tests of Kao (1999) are reported in Table 4-25, where the null hypothesis of no cointegration is also rejected at the 5 per cent significant level.

4.6.3 **Finland – panel Granger causality results**

As seen in Table 4-27, we are not able to see signs of short run causality moving from ICT and non-ICT to value added growth and TFP, which suggests that GDP and TFP growth will not be influenced by the contribution of ICT and non-ICT growth. In addition, it does not possess an effect on these variables in the short run and that the policies for increasing ICT-producing industries may not retard GDP growth.

In this sense, there is unidirectional causality among ICT, non-ICT and value added growth as well as among ICT, non-ICT and TFP growth in the short run. Moreover, the results demonstrate evidence of short run causality between L and EG ,the same as TFP and EG in the short run, implying that a 1 per cent increase in labour employment and

TFP growth may lead to a 0.32 per cent and 0.31 per cent rise, respectively, of value added growth in the short run.

With respect to the TFP results in the last row, the impact of ICT on TFP is insignificant and positive (0.2648) in the short run while effect is significant and negative (-0.702) in the long run. This evidence is in a line with Gordon (2000); Jorgenson (2001); Jorgenson and Stiroh (2000), Sichel and Oliner (2002) who contended that technological progress in ICT stimulates growth of TFP in industries, and, hence, of aggregate TFP in the long run.

Table 4-27. Panel causality test results, Finland

Dependent Variable	*Source of Causation (independent variable)*						*Estimation Method , Based on Hausman Test*
	Short Run					*Long Run*	
	ΔEG	ΔL	ΔICT	Δnon-ICT	ΔTFP	ECT	
ΔEG	-----	0.3211* (0.000)	-0.2569 (0.392)	-0.0479 (0.886)	0.3119* (0.000)	-0.6672* (0.000)	PMG
ΔL	0.3492* (0.000)	-------	0.2366 (0.469)	0.1169 (0.757)	-0.3306* (0.000)	-0.6257* (0.000)	PMG
ΔICT	0.0752* (0.009)	-0.0700* (0.015)	------	-0.0572 (0.130)	-0.0749* (0.010)	-0.5380* (0.000)	DFE
Δnon-ICT	-0.0281 (0.556)	0.0127 (0.784)	0.2515* (0.008)	-------	0.0299 (0.529)	-0.8901* (0.000)	DFE
ΔTFP	0.3089* (0.000)	-0.2973* (0.000)	0.2648 (0.409)	0.1579 (0.662)	--------	-0.7021* (0.000)	PMG

Note: The reported values in parentheses are the p-values of the F-test.
*indicates significant at the 5% level, **indicates significant at the 10% level.

Source: Author, 2013

Thus, from Table 4-27, we would state that the recorded ECT coefficients in the last column are significant and negative representing that any divergence of output growth from the long run equilibrium level leads to a change in the contrary direction. The magnitude of the ECT coefficient is near to unity, which shows a fast speed of adjustment of output to its long run trend (Dimelis & Papaioannou, 2011).

Table 4-28. Panel industries direction of causality in short run and long run, Finland

Direction of Causality	*Wald F-test*	*Direction of Causality*	*Wald F-test*
ΔEG ←-------→ ΔL	(0.000)* (0.000)*	EG ←-------→ L	(0.000)* (0.000)*
ΔEG ---------→ ΔICT	(0.392) (0.009)*	EG ←-------→ ICT	(0.000)* (0.000)*
ΔEG No Causality Δnon-ICT	(0.886) (0.556)	EG ←-------→ non-ICT	(0.000)* (0.000)*
ΔEG ←-------→ ΔTFP	(0.000)* (0.000)*	EG ←-------→ TFP	(0.000)* (0.000)*
ΔL ---------→ ΔICT	(0.469) (0.015)**	L ←-------→ ICT	(0.000)* (0.000)*
ΔL No Causality Δnon-ICT	(0.757) (0.784)	L ←-------→ non-ICT	(0.000)* (0.000)*
ΔL ←-------→ ΔTFP	(0.000)* (0.000)*	L ←-------→ TFP	(0.000)* (0.000)*
ΔICT ---------→ Δnon-ICT	(0.130) (0.008)*	ICT ←-------→ non-ICT	(0.000)* (0.000)*
ΔICT ←--------- ΔTFP	(0.010)* (0.409)	ICT ←-------→ TFP	(0.000)* (0.000)*
Δnon-ICT ←-------→ ΔTFP	(0.662) (0.529)	non-ICT ←-------→ TFP	(0.000)* (0.000)*

Note: The reported values in parentheses are the p-values of the F-test.
*indicates significant at the 5% level, **indicates significant at the 10% level.

Source: Author, 2013

The F-test is employed to establish whether a short run and long run causality relationship is present between the variables by means of examining the significance of the lagged levels of the variables and error correction term. The computed F-statistics under the null hypothesis of no long run causality relationship are denoted as F (EG| L, ICT, non-ICT, TFP), F (L| EG, ICT, non-ICT, TFP), F (ICT| EG, L, non-ICT, TFP), F (non-ICT| EG, L, ICT, TFP), and F (TFP| EG, L, ICT, non-ICT) for each equation (3.21)-(3.25), respectively.

The results in Table 4-28 show long run bidirectional Granger causality running from real GDP growth to the contribution of L, ICT, non-ICT, and TFP growth at the 5 per cent significant level, respectively. As a result, contrary to Gholami (2006), and Ark et al. (2003) at the aggregate level, ICT is only the determinant factor for economic and TFP growth in Finland in the long run. There is no causal relationship between GDP growth and non-ICT capital during the period in the short run.

We conclude that the short run results that increase the economic growth and TFP cause a rise in the contribution of ICT to growth whereas the latter does not cause output and TFP growth of Finnish industries. The long run results about the impact of ICT on GDP growth is consistent with the research of Jalava and Pohjola (2003, 2007) in Finland that considered that the contribution from increases in ICT capital magnitude was boosted to 0.46 per cent. They stated that the rest of output growth in Finland was related to TFP growth in ICT-production, particularly in the telecommunication production sector.

4.6.4 **Finland – long run relationship by System GMM**

In the one-step System GMM regressions, a moderate solution is followed by choosing one lag of the dependent and level of ICT_non-ICT binary variable as instruments. In the two-step System GMM, we found one lag of the dependent and ICT_USE and ICT_PROD binary variables as appropriate instruments. Given that the data we are using extends over a time span of 17 years, it is large enough to address the problem of stability, which was a concern for Bond, Hoeffler, and Temple (2001) when the number of observations are small (Hosseini Nasab & Aghaei, 2009).

In looking at Table 4-29 for the results of Hansen J test, the strategy of choosing instruments is justified, in the one-step and two-step results. There is a failure in the rejection of the initial hypothesis that the instrumental variables are uncorrelated to the residuals, so they are valid instruments.

According to the results of the two-step System GMM (columns 3 and 4), ICT does not have any significant effects. Consequently, all the binary variables that are related to ICT like ICT_PROD ICT_USE, and ICT_non-ICT lost their significant effects to value added growth.

Table 4-29. Long run panel data estimators for industries, Finland

Independent Variables	*Dependent variable:EG*			
	System GMM Estimates, One-step		*System GMM Estimates, Two-step*	
	(1)	*(2)*	*(3)*	*(4)*
L	0.949* (0.000)	0.946* (0.000)	0.939* (0.000)	0.942* (0.000)
ICT	0.666* (0.000)	0.946* (0.000)	0.755 (0.251)	0.937* (0.000)
Non-ICT	0.911* (0.000)	0.972* (0.000)	0.935* (0.000)	0.971* (0.000)
TFP	0.989* (0.000)	0.994* (0.000)	0.988* (0.000)	0.992* (0.000)
ICT_PROD	0.379* (0.018)	------	-0.078 (0.921)	-----
ICT_USE	0.331 (0.216)	------	0.112 (0.942)	-----
ICT_nonICT	0.059 (0.265)	------	0.111 (0.414)	-----
Constant	0.360* (0.000)	0.278* (0.000)	0.307** (0.072)	0.281* (0.000)
Obs	378	378	357	357
Industries	21	21	21	21
Wald test	75075.62	1482.95	25233.91	37502.84
Sargan test(p-value)a	0.004	0.003	0.003	0.002
Hansen test (p-value)b	1.000	1.000	1.000	1.000
Serial correlation test AR(2) (p-value)c	0.795	0.796	0.954	0.987
Serial correlation test AR(3) (p-value)d	0.579	0.604	0.593	0.315

a.Sargan test is evaluating overidentifying restrictions in Ivs. The null hypothesis is that the instruments used in the regression are valid.
b. Hansen test is evaluating overidentifying restrictions in GMM. The null hypothesis is that the instruments used in the regression are exogenous.
c. d. The null hypothesis is that the error in the first-difference regression exhibits no first or second order serial correlation.
The values in parentheses denote the significance level for rejection.
*Indicate that the parameters are significant at the 5% level.
**Indicate that the parameters are significant at the 10% level.

Source: Author, 2013

If we consider the results of the first column, it appears that higher returns were enjoyed by the ICT-producing industries, relative to the ICT-using industries. Particularly, the estimates indicate that the contribution of ICT in ICT-producing industries was 0.37 per cent higher, and, in ICT-using industries, it was 0.33 per cent higher, in comparison with the remaining industries. Therefore, the findings of the one-step evidence is in line with the Finnish growth decomposition that Finland was not as fast in utilizing information technology as it was in adopting telecommunications technology (Jalava, 2003; Jalava & Pohjola, 2002, 2007). There is special relevance in a country like Finland due to the benefits it reaped from Nokia. The case in point is a successful production of a new technology, while, in other industries, much improvement is needed to use new technology for the process of production.

Furthermore, ICT has an impact on growth via its strong effect on total factor productivity (0.98%) gains induced by rapid technological advances in the ICT-producing industries. However, considering the arguments of O'Mahony (2005) and Ark et al. (2003), there is a strong potential for the exploitation of growth benefits in the service industries in Finland where ICT use is intensive. Insignificant coefficient of ICT_nonICT in columns 1 and 3 show that between ICT and non-ICT capital no significant complementary effects exist. To sum up, due to the System GMM results, the largest part of growth in the Finnish sectors is sourced from TFP, non-ICT and ICT, especially ICT-producing sectors.

On the other hand, the reported results in these columns indicate that the productivity effects of ICT are significantly higher in the ICT-using industries. It might be concluded that the beneficial effects of ICTs are not concentrated on investment in ICT-producing industries in Finland because of the negative effects of ICT-producing industries. In contrast, the efforts to increase the use of ICT services in companies and industries will stimulate GDP growth.

4.6.5 Justification of insignificant effects of ICT on TFP and GDP growth in Finland

Even though it is well known that ICT is a driving force of economic growth there are still few proofs that show that ICT can also have a negative effect on economic growth. Furthermore, in the study of 43 countries spanning from 1985 to 1999, no significant relationship was found between economic growth and ICT investment (Pohjola, 2002). Another research conducted on 84 countries from the period spanning from 1990 to

1999 revealed that there was no significant positive impact on economic growth by the penetration of computers; however, Jacobsen (2003) did find a positive relationship between economic growth and mobile phones (Jacobsen, 2003). The negative contribution to economic growth by computers due to the high cost of new ICT investment is explained by the application of the traditional growth accounting framework in the US (Kiley, 1999).

Computers and related services are sectors that account for much of the production of software. In Finland, in the last 30 years, the share of business sector value added has been increased by service-related ICT-industries (Eberhardt, 2011). Previous research indicated that, in Finland, a significant role has been played by the ICT sector since the mid-1990s. Therefore, it is concluded that Finland depends more on ICT-production to further boost economic growth.

Hence, based on the GDP share of the ICT-producing sector (5.41 per cent), which is "electrical and optical equipment" industries, it is claimed that the "Nokia" company, which is one of the well-known producers of mobile phones in the last decade, has performed poorly in marketing and updating smart phone applications for contributing more GDP growth. Although in Finland there was a five-fold rise in the contribution of "electrical and optical equipment" from 4.78 per cent to 20.7 per cent between 1990 and 2007, recently, Finland's telecommunications manufacturing industry (Nokia) has lost competitive power in the world market, which is probably the essential driver of economic growth. Remarkably, however, the diffusion of ICT has become sluggish in Finland compared to some other EU countries calculated by the portion of software packages in private non-residential fixed properties (Jalava & Pohjola, 2008).

Justification for the use of the "electrical and optical equipment" industry can be derived from the studies of Jorgenson and Stiroh (2003) who found that much of the recent US growth recovery occurred in ICT producing sectors. Thus, in this research "electrical and optical equipment" industry is also introduced as an ICT-producing industry. Extensively ICT-using industries were considered while the coefficient of ICT capital became significant in the PMG estimation results, which, for Finland, are listed as the "Agriculture, hunting, forestry and fishing", "Food, beverages and tobacco", "Transport equipment", “Manufacturing and recycling", and "Finance, insurance, real estate and business services" industries.

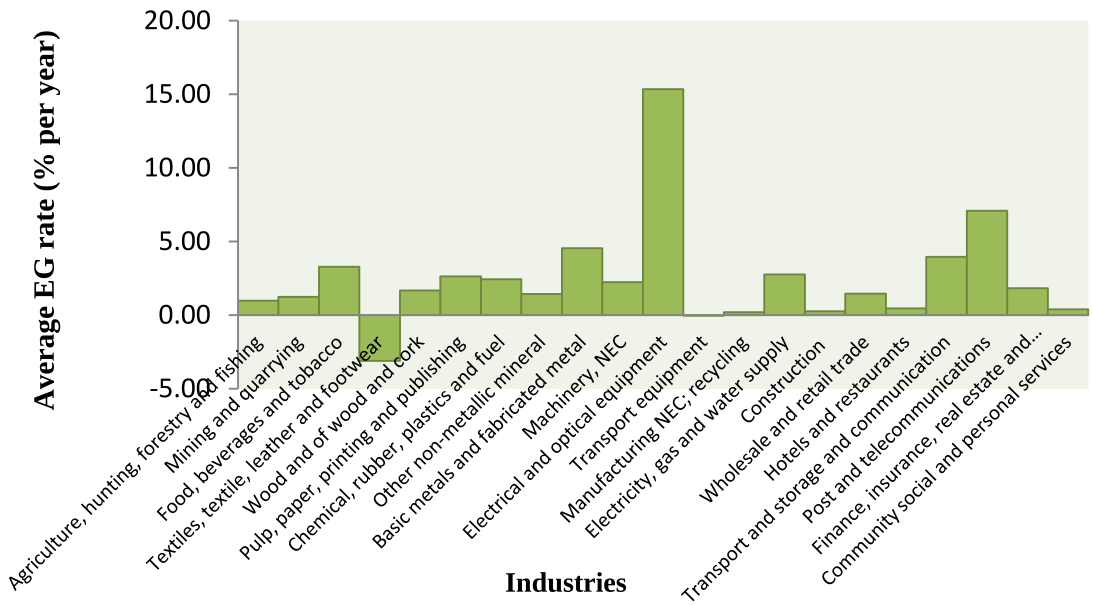

Figure 4-12. Average growth rate of value added for each industry, Finland
Source: Author Analysis, 2013

According to Figure 4-12, the "electrical and optical equipment" industry in Finland has the highest proportion of value added growth by an average 15.34 per cent growth rate per year attributed to the other sectors, while this sector has been considered as an ICT-producing sector. Therefore, the economic growth of Finland is influenced by the ICT-producing sector while ICT has an insignificant impact on Finnish industries. Thus, our synthetic analysis from Figure 4-12, PMG and GMM estimators’ results have illustrated two important points. First, due to the catch up, GDP growth must be stimulated to increase the ICT contribution of industries that are impressive on GDP growth, such as the ICT-producing industry. Second, TFP growth is the biggest contributor of GDP growth in Finland (59 per cent). Based on the causality results, ICT is not a source of TFP growth in the short run, thus GDP growth in the long run could not attribute to the spillover effects of ICT through TFP growth. The finding is fascinating because we are unaware of the solid evidence for ICT spillovers within Finland. The proof is weak, as it seems to be for the period 1990-2011; therefore ICT is not effective on GDP growth, which leads to the insignificant effects of ICT on value added growth.

The difference in the impacts of TFP and ICT investments from ICT goods production can partially explain the Intra-EU differences of labour productivity growth. There was a strong decline in the productivity growth rates in some of the EU’s largest economies like Italy, France, the UK, Germany, and, more importantly, Spain. While, smaller countries were facing acceleration in their labour productivity growth, such as Austria, Finland, Sweden and Ireland, it is not easy to explain these differences. The increased availability of ICT might be a factor as well as to how there are different responses to the provided opportunities, such as different industrial structures and varying degrees of openness of the economies.

It has been shown in various studies that in the US a major role has been played by the rapid technological development in the ICT-producing industries in the revival of TFP growth (Jorgenson et al., 2005; Oliner & Sichel, 2002; Jorgenson, 2001). On average, the GDP share of the ICT producing industries is not similar among European countries, which may be one of the reasons for the more sluggish TFP growth in Europe over 1995 to 2001. Although the GDP share for ICT-production differs among the European countries, it may also be a driver of intra-EU differences in TFP growth. Within the EU, it has been argued that productivity differentials between the member countries is related to non-ICT sources (Timmer & Van Ark, 2005), while the benefits from high shares of ICT-goods production and high ICT capital investment were reaped by some EU countries, such as Sweden, Finland and Denmark.

Despite the increasing rate of ICT contribution from 0.19 per cent to 0.86 per cent, the GDP growth rate of Finland decreased to 3.73 per cent. As many industrial countries have recently suffered a slowdown in productivity, Finland has done somewhat better as it has not been affected by a productivity slowdown to the same extent as other countries.

In the early 1990s, when the expansion phase in countries, such as the United States, started, Finland faced deep economic recession. The negative contribution on economic growth by computers may be explained by the high adjustment costs of ICT growth when there was a surge of investment in Finland. Economic growth can be decreased due to the introduction of new investment goods like smart phones and software, which can impose large adjustment costs to the economy.

4.7 Denmark – Growth Decomposition

In considering EU countries, most of the contribution in TFP growth is made by ICT-production (i.e. the production of office equipment and computers, communication equipment and semiconductors) in Finland, Portugal, the UK and Ireland but less in Denmark, Spain and Austria. In Denmark, the most important category of investment in ICT is software, which is at 76 per cent (Aghion & Howitt, 1997).

Table 4-30. Denmark growth decomposition

Variable	Obs	Mean	Std. Dev.	Min	Max
EG(%)	378	1.12	7.77	-43.39	25.79
L(%)	378	-0.40	3.08	-15.14	10.53
ICT(%)	378	0.65881	0.679019	-0.61	3.59
non-ICT(%)	378	0.516349	0.977029	-1.39	7
TFP(%)	378	0.158386	7.325936	-46.32	25.2

Source: EU KLEMS Database, 1990-2007

From previous findings, country performance is very different within the EU countries. Ireland, the Netherlands as well as the United Kingdom have registered solid growth of ICT capital and a massive contribution from ICT service runs to productivity growth.

Nevertheless, based on Table 4-30 and Figure 4-13, in Denmark, although ICT contribution is higher than other factors (38 per cent) it does not flow to productivity because the contribution of TFP growth is only 9 per cent. Most importantly, countries such as Denmark, are represented by relatively greater shares for software, which shows substantial diffusion while, so far, it fails to be translated into substantial acceleration of the productivity growth of these countries (Aghion & Howitt, 1997).

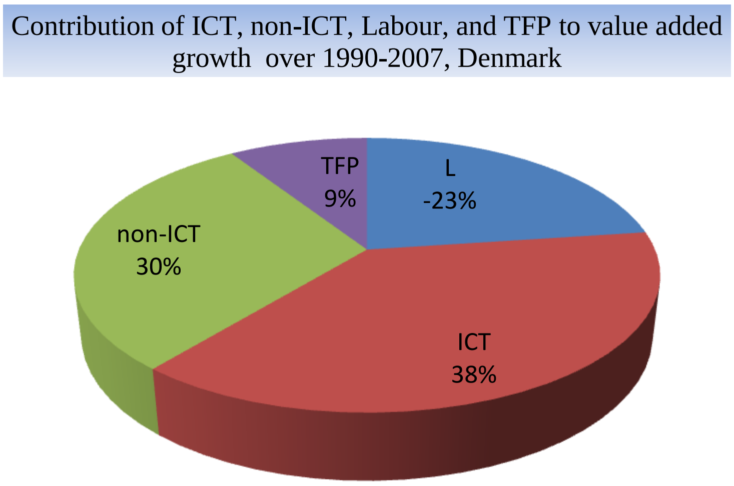

Figure 4-13.Contribution of ICT, non-ICT, Labour, and TFP to value
Source:EU KLEMS Database, 1990-2007

Figure 4-13 illustrates the productivity paradox in the Danish sectors, which shows the absence of strong ICT effects on TFP growth for the period of 1990-2007. These results are in a line with those of Van Ark et al. (2003, 2007) who investigated the productivity paradox in selected developing countries for the period 1995-2003. Denmark's ICT-production industry in hardware is relatively smaller compared to other EU countries, and in contrast to Japan and Finland. Disparities in the contribution of TFP not exactly associated with ICT could still be in some way due to the ICT-revolution. Industry level research of US growth identified that the essential contributing sectors to the acceleration of TFP are retail trade, financial services and wholesale sectors, which might all be highly intensive users of ICT (Jorgenson & Nomura, 2005; Triplett &

Bosworth, 2004; Triplett, 1999). If one country has higher ICT-using sectors, it will create positive spillover on TFP growth. On the other hand, countries with higher levels of ICT investment like Finland as well as Sweden had excessive TFP growth rates. However, in other ICT intensive countries like Denmark and Japan, TFP growth held slowed down.

4.7.1 **Denmark – panel unit root tests**

Before running the cointegration approaches, we have to verify the order of integration of each variable. Implementing the panel unit root tests, formulated by Maddala & Wu (1999), Breitung (2000), Hadri (2000), and Levin et al. (2002), which prohibit for heterogeneity in the autoregressive coefficient, will probably be the solution to identify the integration order. These tests, as the first generation panel unit root tests, include the disadvantage of presuming independent cross-sections. On the other hand, it has been found in the literature that cross-section dependency may arise as a result of several unobserved reasons, externalities, regional and macroeconomic linkages and also unaccounted residual interdependence.

Currently, a number of the new panel unit root tests have emerged that resolve the question of the dependence, and, also, the correlation presented the popularity of macroeconomic dynamics and linkages. These types of test are named the second-generation panel unit root tests. A well-known second-generation test is regarded in this research as Pesaran's (2003) cross-sectional. We have applied the first and second-generation panel unit root test.

The findings of the first and second-generation panel unit root tests without trend are both presented in Table 4-31. For most of the five variables (except ICT in Breitung and Pesaran tests and TFP in the Levin-Lin-Chu test), the null hypothesis of the unit roots could not be rejected at level. The outputs robustly reveal that the variables at level are non-stationary as well as being stationary in first differences at the 5 per cent and 10 per cent significant level.

Table 4-31. Denmark panel unit root tests

Method	EG	L	ICT	Non-ICT	TFP
Breitung(2000)					
Level	0.268(0.606)	1.182(0.881)	-1.849*(0.032)	-1.202(0.115)	-0.809(0.209)
First difference	-9.992*(0.000)	-8.408*(0.000)	-2.853*(0.002)	-3.093*(0.001)	-10.387*(0.000)
Hadri(2000)					
Level	3.964*(0.000)	3.046*(0.001)	6.648*(0.000)	2.512*(0.006)	3.839*(0.000)
First difference	0.668(0.252)	-0.899(0.816)	-0.558(0.712)	-1.558(0.940)	0.547(0.292)
Pesaran (2003)					
Level	0.318(0.625)	-1.269(0.102)	-2.589*(0.005)	-0.739(0.230)	-0.401(0.344)
First difference	-5.123a*(0.000)	-3.522a*(0.000)	-8.346a*(0.000)	-5.167a*(0.000)	-5.605a*(0.000)
Maddala &Wu (1999) Fisher					
Level	-0.125(0.549)	-1.578(0.943)	-0.069(0.527)	1.164(0.122)	-1.671(0.953)
First difference	1.911*(0.028)	1.896*(0.029)	3.545*(0.000)	3.314*(0.001)	4.594*(0.000)
Levin-Lin-Chu(2002)					
Level	-1.265(0.103)	0.983(0.837)	-0.841(0.200)	0.412(0.659)	-1.324**(0.093)
First difference	-4.209*(0.000)	-6.585*(0.000)	-6.451*(0.000)	-6.400*(0.000)	-4.267*(0.000)

Notes: The null hypothesis is that the series is a unit-root process except the Hadri(2000) test.
P-values are given in parentheses.
Probabilities for the Fisher-type tests are computed using an asymptotic Chi-square distribution. All the other tests are assumed to be asymptotic normal. The lag length is selected using the Modified Schwarz Information Criteria.
* Indicates the parameters are significant at the 5% level.
**Indicates the parameters are significant at the 10% level.
[a]all of values are z(t-bar).

Source: Author, 2013

4.7.2 **Denmark – panel cointegration tests**

Kao (1999) presented two types of cointegration tests in panel data, the Dickey-Fuller (DF) and Augmented Dickey-Fuller (ADF) type tests. Where the ρ ADF test is less than the probability of 1per cent then the null hypothesis of no cointegration will be rejected. If the Kao (1999) test result confirms the existence of a long run relationship, we can conclude that all the variables in this section are cointegrated together.

Table 4-32.Kao's residual cointegration test results

	Lag [a]	t-statistic	Probability
ADF	3	-3.571248*	0.0002

Note: Null Hypothesis: No cointegration,
[a] lag selection using Parzen kernel,
*Indicate that the parameters are significant at the 5% level.

Source: Author, 2013

To ensure that there is a cointegration relationship we can apply another panel cointegration test named the Pedroni (1999, 2004) test. Pedroni (1999, 2004) suggests the use of two cointegration tests (panel and group) to test the null hypothesis of no cointegration. The panel tests are determined by the dimension method, which includes four statistics. All these statistics basically pool the autoregressive coefficients across various countries for the unit root tests on the expected residuals, considering common time aspects and heterogeneity across countries. The set tests are calculated on the dimension approach, which includes three statistics. All these statistics are determined by averages of the individual autoregressive coefficients linked to the unit root tests of the residuals for every country in the panel. Table 4-33 reviews both the within and between dimension panel cointegration test statistics. All of the test statistics apart from the Panel rho-Statistic and Group rho-Statistic reject the null hypothesis of no cointegration at the 1 per cent significant level.

Table 4-33.Pedroni's (2004) panel cointegration test

Alternative hypothesis: common AR coefs. (within-dimension)		
	Statistic	Prob.
Panel v-Statistic	1.672848	0.0472
Panel rho-Statistic	0.169867	0.5674
Panel PP-Statistic	-2.372247	0.0088
Panel ADF-Statistic	-2.688975	0.0036
Alternative hypothesis: individual AR coefs. (between-dimension)		
	Statistic	Prob.
Group rho-Statistic	1.064935	0.8565
Group PP-Statistic	-4.440376	0.0000
Group ADF-Statistic	-3.515093	0.0002

Notes: The null hypothesis is that the variables are not cointegrated.
Under the null tests, all the statistics are distributed as normal (0, 1).
*Indicate that the parameters are significant at the 5% level.

Source: Author, 2013

In addition, the results of Kao (1999) showed that the null hypothesis is rejected at the 1 per cent significant level; therefore, this finding has resolved doubts of the existence of a cointegration relationship from the Pedroni (2004) tests.

4.7.3 **Denmark – panel Granger causality results**

The concept of cointegration can be defined as a systematic co-movement among two or more economic variables in the long run. If each variable is non-stationary and cointegrated, then any standard Granger-causal inferences will be invalid and a more comprehensive test of causality based on an error correction model (ECM) should be adopted (Engle & Granger, 1987). In the previous section, we found cointegration among five variables in the Danish sectors. The expanded multivariate causality model based on ECM through equations (3.21)-(3.25) were estimated in the following. The choice among MG, PMG, and DFE estimators in order to estimate ECM implies a consistency-efficiency trade off. To identify which estimator is more suitable, we primarily rely on the Hausman (1978) specification test and F-test. Table 4-34 illustrates the panel causality model results for the Danish sectors.

Table 4-34. Panel causality test results, Denmark

Dependent Variable	*Source of Causation (independent variable)*						*Estimation Method, Based on Hausman Test*
	Short Run					*Long Run*	
	ΔEG	ΔL	ΔICT	Δnon-ICT	ΔTFP	ECT	
ΔEG	-----	0.1056 (0.617)	0.0330 (0.855)	0.1038 (0.611)	0.1134 (0.592)	-0.8841* (0.000)	DFE
ΔL	0.7924* (0.000)	-------	-1.0024* (0.000)	-0.8346* (0.000)	-0.7733* (0.000)	-0.2102* (0.029)	PMG
ΔICT	0.2664* (0.004)	-0.2544* (0.003)	------	-0.1473 (0.244)	-0.2660* (0.004)	-0.3968 * (0.000)	PMG
Δnon-ICT	0.1733* (0.012)	-0.1475* (0.030)	-0.0593 (0.481)	-------	-0.1754* (0.011)	-0.3578* (0.000)	PMG
ΔTFP	0.8860* (0.000)	-0.8383* (0.000)	-1.2128* (0.000)	-0.8376* (0.002)	--------	-0.1301 (0.159)	PMG

Note: The reported values in parentheses are the p-values of the F-test.
*indicates significant at the 5% level, **indicates significant at the 10% level.

Source: Author, 2013

With respect to the ICT effect on output growth, we could observe that the estimated short run effect for the period 1990-2007 is insignificant, while the non-ICT, labour and TFP impacts are also insignificant in the short run. In contrast, all of these production factors have significant effects on output growth in the long run. The negative and significant coefficient of ECT in the first row of Table 4-34 proves a long run relationship on these variables while EG is the dependent variable.

Denmark's results in the last row of Table 4-34 confirms that the impact of ICT on TFP is negative (-1.21) and significant at the 5 per cent level. This result is in line with the theoretical expectation that the impacts of ICT are predicted with a time lag at the industrial level. Empirically, Daveri (2002) displayed proof for a decreasing productivity impact of ICT capital in the Danish economy. Similar evidence has been provided by the report of the "Danish ICT Industry Innovation for Society" (2011) for its industries. Moreover, a major source of TFP growth is the annual output growth, which has a significant positive effect on TFP in the short run (0.8860) as well as the long run (0.1301). We should point out that the reported error correction coefficients in the last column are negative and statistically significant indicating that any specific discrepancy of output from the long run equilibrium level creates an adjustment in a different way.

Table 4-35. Panel industries causality direction in short run and long run, Denmark

Short Run causality		*Long Run causality*	
Direction of Causality	*Wald F-test*	*Direction of Causality*	*Wald F-test*
ΔEG ---------→ ΔL	(0.617) (0.000)*	EG ←-------→ L	(0.029)* (0.000)*
ΔEG ---------→ ΔICT	(0.855) (0.004*	EG ←-------→ ICT	(0.000)* (0.000)*
ΔEG ---------→ Δnon-ICT	(0.611) (0.012)*	EG ←-------→ non-ICT	(0.000)* (0.000)*
ΔEG ---------→ ΔTFP	(0.592) (0.000)*	EG ←--------- TFP	(0.000)* (0.159)
ΔL ←-------→ ΔICT	(0.000)* (0.003)*	L ←-------→ ICT	(0.029*) (0.000)*
ΔL ←-------→ Δnon-ICT	(0.000)* (0.030)*	L ←-------→ non-ICT	(0.029)* (0.000)*
ΔL ←-------→ ΔTFP	(0.000)* (0.000)*	L ←-------→ TFP	(0.029)* (0.159)
ΔICT no Causality Δnon-ICT	(0.244) (0.481)	ICT ←-------→ non-ICT	(0.000)* (0.000)*
ΔICT ←-------→ ΔTFP	(0.004)* (0.000)*	ICT ←-------→ TFP	(0.000)* (0.159)
Δnon-ICT ---------→ ΔTFP	(0.011* (0.002)*	non-ICT ←-------→ TFP	(0.000)* (0.159)

Note: The reported values in parentheses are the p-values of the F-test.
*indicates significant at the 5% level, **indicates significant at the 10% level.

Source: Author, 2013

The results in Table 4-35 only show the long run bidirectional Granger causality testing GDP growth to the contribution of L, ICT, and non-ICT growth at the 5 per cent significant level. There is a unidirectional long run Granger causality flow from TFP growth to the contribution of ICT, non-ICT, labour and GDP growth at the per cent significant level whereas short run Granger causality ran from EG to TFP.

Therefore, ICT investment growth cannot be a short run target of the growth policy in Denmark but can be targeted as a long run policy. Danish industries are able to pay more attention to the ICT spillover effects through TFP growth in the short run and dramatically increase income growth by high TFP in the long run.

4.7.4 **Denmark – long run relationship by System GMM**

To estimate equation (3.15), the System GMM is employed, which controls the endogeneity issue and serial correlation of regressors. The estimated parameters are presented below in Table 4-36. Regarding Danish industries, the System GMM estimates illustrate that the output elasticises of ICT (1.34 per cent) and non-ICT (1.99 per cent) capital are largely positive and mainly significant at the 5 per cent level. The positive and significant overall ICT contribution is observable in both the one-step and two-step results from columns 1 and 3. These results are in line with the long run PMG estimators but in contrast to the PMG short run results; thus implying that ICT can get an imperative role in enhancing growth among the Danish industries, through its faster ICT capital accumulation in the long run.

It is indicated by the estimates of column 1 that there were significantly higher returns to ICT in the ICT-producing industries and the results are the same in column 3 but with insignificant coefficients. Particularly, the estimates derived indicate that the contribution of ICT was 0.34 per cent higher in producing ICT and -0.32 per cent smaller in industries using ICT (when comparing with the remaining industries).

Table 4-36. Long run panel data estimators for industries, Denmark

Independent Variables	*Dependent variable:EG*			
	System GMM Estimates, One-step		*System GMM Estimates, Two-step*	
	(1)	*(2)*	*(3)*	*(4)*
L	0.919* (0.000)	0.921* (0.000)	0.845* (0.000)	0.946* (0.000)
ICT	1.099* (0.000)	1.116* (0.000)	1.344** (0.072)	1.126* (0.021)
Non-ICT	1.025* (0.000)	0.995* (0.000)	1.991* (0.005)	1.128* (0.000)
TFP	0.998* (0.000)	0.998* (0.000)	0.991* (0.000)	1.007* (0.000)
ICT_PROD	0.345** (0.073)	---------	4.493 (0.332)	
ICT_USE	-0.322 (0.134)	------	-2.198 (0.455)	-----
ICT_non-ICT	0.019 (0.618)	------	-0.365 (0.192)	-----
Constant	0.089 (0.109)	0.081 (0.115)	-0.380 (0.466)	-0.555 (0.513)
Obs	378	378	378	378
Industries	21	21	21	21
Wald test	32620.36	1979.36	37463.06	92368.23
Sargan test(p-value)[a]	0.000	0.000	0.000	0.000
Hansen test (p-value)[b]	1.000	1.000	1.000	1.000
Serial correlation test AR(2) (p-value)[c]	0.217	0.212	0.238	0.177
Serial correlation test AR(3) (p-value)[d]	0.343	0.346	0.247	0.324

a. Sargan test is evaluating overidentifying restrictions in Ivs. The null hypothesis is that the instruments used in the regression are valid.
b. Hansen test is evaluating overidentifying restrictions in GMM. The null hypothesis is that the instruments used in the regression are exogenous.
c. d. The null hypothesis is that the error in the first-difference regression exhibit no first or second order serial correlation.
The value is in parentheses denote the significance level for rejection.
*Indicate that the parameters are significant at the 5% level.
**Indicate that the parameters are significant at the 10% level.

Source: Author, 2013

From the results reported in the third column of Table 4-36, there was a sizable and significantly higher growth impact of ICT on ICT-using and ICT-producing industries (interaction terms of ICT_USE and ICT_PROD, respectively). It seems that this proof is in line with the findings that there is a strong link between Denmark's productivity advantage and industries that are either heavy users of ICT or ICT-producers. Moreover, it seems that higher returns were enjoyed by the industries producing ICT, relative to the ones using ICT. Thus, there are considerably higher productivity effects of ICT in the industries producing ICT. Combined with the results from previous analyses, it may be concluded that the beneficial effects of ICT are mostly concentrated in ICT intensive industries (Van Ark, Inklaar, & McGuckin, 2003; Jorgenson, Ho, & Stiroh, 2003). Particularly, the estimates derived indicate that contribution of ICT was 4.49 per cent higher in industries producing ICT and 2.19 per cent higher in industries using ICT relative to the remaining industries in the EU.

The results of column 1 and 3 do not show a significant complementary relationship between non-ICT and ICT capital exists (interaction term ICT_non-ICT). We have employed the lagged value of the dependent variable and interactions of ICT_USE, ICT_PROD, and ICT_non-ICT as instruments. As mentioned previously, the reliability of GMM estimator is hedged on the validity of the instruments, which is used in the System GMM regression and the absence of the third-order and second-order serial correlation in the error term. It is for this very reason, that in Tables 4-36, we reported the results of the Hansen J test, second-order, third-serial correlation test, and Sargan test. The Hansen J test accepts the null hypothesis, which states the validity of the instruments used in the regressions. Moreover, the null hypothesis is accepted by the tests that examine the second and third-order serial correlation, meaning that there is no exhibition of second and third-order serial correlation in the error term. Further support is given by both tests to the reported estimates in Tables 4-36.

4.7.5 **Justification of insignificant effects of ICT on GDP growth in Denmark**

"Post and telecommunications" has the highest share of GDP in comparison to the other industries, which, on average, is a 5.85 per cent contribution to GDP. As in the previous countries, the ICT-producing industry of "Electrical and optical equipment" and ICT-using industries in Denmark are "Agriculture, hunting, forestry and fishing", "Mining and quarrying", "Electrical and optical equipment" and "Transport equipment".

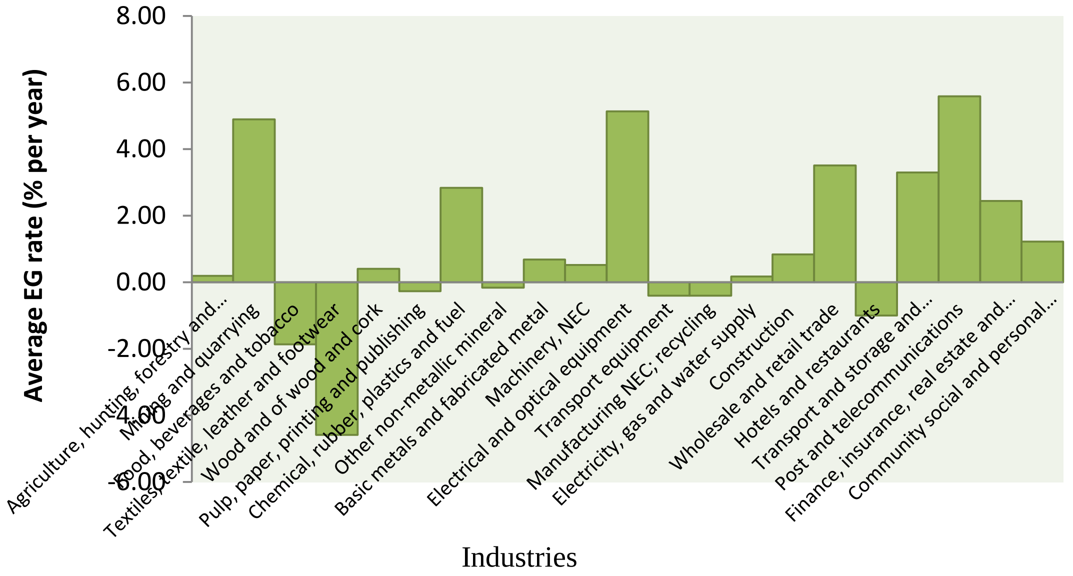

Figure 4-14. Average growth rate of value added for each industry, Denmark
Source: Author’s computation based on dataset from EUKLEMS, 2013

ICT-producing industry has positive significant effects on GDP growth via a 5.14 per cent average contribution to GDP, whereas ICT-using industries have negative insignificant effects on GDP growth via an average 2.46 per cent contribution to GDP. Therefore, despite the positive effects of ICT-producing industry on GDP, more investment in the growth of “Post and telecommunications” is capable of being an engine of GDP growth for Danish industries.

With reference to the previous sections, ICT with more than a 38 per cent contribution to GDP growth is introduced as the main contributor of output growth, while non-ICT is ranked second with a 30 per cent contribution. Therefore, despite the significant effects of ICT on TFP, the insignificant direct effects of ICT have dominated the spillover effects of ICT. Thus, overall, there are no significant effects of ICT contribution for the Danish sectors.

The limited number of ICT-using industries (only 4 industries) is one of the problems of Danish industries limited diffusion and penetration of ICT. These industries also have insignificant and negative effects on GDP growth. The spillover effects of ICT would emerge in all dimensions when the use of ICT becomes widespread in the majority of industries, especially in the key industries of each country. Promoting ICT diffusion among sectors guarantees huge profits for firm competitiveness and economic growth. This is possibly because several EU countries are generally so powerful in developing their ICT-producing industries, ICT diffusion by means of computerization and Internet application is the key to the growth and competitiveness of their economies.

Moreover, Denmark's ICT hardware industry has not become a major driver of economic growth because of the lack of its government's strategic support of the industry's formation and development.

In summing up, it is vital for the Danish government to consider the opportunity of increasing ICT-use in different industries (Vu, 2009). The long run significant effects of ICT show that Denmark is a significantly developed ICT country as well as being a solid environment for strengthening and addressing social and consumer driven requirements, such as health and climate linked concerns. The Danish digital eco-system has a strong technological foundation for system development, integrating hardware and software embedded systems. It also comprises one of the most competitive and advanced telecommunications infrastructure and mobile markets. This will be central for the development of new smart products for applications in health, energy and environment and the future Internet ("Danish ICT Industry Innovation for Society," 2011).

CHAPTER 5: AGGREGATE LEVEL RESULTS AND ANALYSIS

5.1 Introduction

The main purpose of this study is to examine the comprehensive ICT effects on economic growth concerning the top ICT developed countries in Asia-Pacific and Europe. In the literature, there are many works on comparative studies on the EU and the US. In these studies, the ICT development index has been disregarded, especially in Asia-Pacific countries at the industrial level and aggregate level panels. To cover this gap, we have collected aggregate level data for 12 top ranked ICT developed countries in the EU and Asia-Pacific countries from the World Bank Indicator database. In Asia-Pacific and the European zone, we succeeded in collecting all the aggregate data for the six top ranked ICT developed countries, which are reported in Table 5-1. This ranking order is based on the International Telecommunication Union (ITU) in 2011. To be more precise, we have used the EU KLEMS database as the unique database in order to capture the high reliability of our datasets.

Table 5-1. Six top ranking according to the ICT development index (IDI) among EU and Asia-Pacific countries

European Economy	Regional Rank 2010	Global Rank 2010	Asia-Pacific Economy	Regional Rank 2010	Global Rank 2010
SWEDEN	1	2	KOREA(REP)	1	1
ICELAND	2	3	HONG KONG	2	6
DENMARK	3	4	NEW ZEALAND	3	12
FINLAND	4	5	JAPAN	4	13
LUXEMBOURG	5	7	AUSTRALIA	5	14
SWITZERLAND	6	8	SINGAPORE	6	19

Source: International Telecommunication Union (ITU), 2011

Therefore, we will classify our results according to the industrial level and aggregate level. The industrial level findings are reported in our analysis for each individual country, whereas the aggregate level findings show two groups of results for panels – Asia-Pacific and EU countries. In the aggregate level data, despite the comparative study between Asia-Pacific panels and EU panels, we can investigate the relationship of the countries global rank in ICT development and the significance of ICT impact on economic growth.

5.2 Asia-Pacific and European Growth Decomposition

According to the literature, a disproportionate amount of the share in the global ICT-production is captured by Asian countries. In 1998, it accounted for almost 40 per cent of the value of all electronics production in the world (Wong, 1998). Nevertheless, generally, these countries are not new economies but could be seen as slowing down in the adoption of using information, communication technology. An analysis regarding ICT investment was conducted across 12 Asia Pacific countries using economic development data at different levels from 1984 to 1990 (Kraemer & Dedrick, 1994). At the national level, a significant relationship was found between the ICT investment growth rate, and economic growth and productivity. Youn (1995) and Krugman (1994) indicated that an increase in capital intensity was the main driver of the major growth in Asia rather than TFP growth.

The main cause of higher GDP growth in Korea and Hong Kong is associated with the high growth rate of TFP and non-ICT contribution, which is not the case for Sweden and Iceland as EU countries. It is important to note that in Tables 5-2 and 5-3, Singapore with the highest economic growth rate of 6.634% annually among all 12 countries, has been the fourth largest contributor of ICT after Finland with 0.67 per cent.

According to Tables 5-2 and 5-3, the highest contribution of ICT is Australia (0.65 per cent) with 3.246 per cent annual GDP growth in Asia-Pacific countries while the top most contributor of ICT in the EU zone is Switzerland (1.435 per cent) with an annual growth rate of 3.283 per cent..

Table 5-2. Asia-Pacific growth decomposition

Country	EG(%)	L(%)	ICT(%)	Non-ICT(%)	TFP(%)
KOREA	5.361	0.709	0.484	1.141	2.571
HONG KONG	4.032	0.141	0.300	1.213	1.446
NEWZLAND	2.554	0.436	0.655	0.532	-0.071
JAPAN	1.172	0.315	0.262	0.617	-0.024
AUSTRALIA	3.246	0.207	0.650	1.466	-0.093
SINGAPORE	6.634	0.700	0.540	1.136	1.341
TOTAL	3.843	0.418	0.482	1.018	0.861

Source: Author's computation based on data from World Bank Development Indicators, 2013

Based on the dataset from the World Bank Development Indicators, the mean value of EG, L, ICT, non-ICT and TFP growth from 1990-2011 is calculated for both Asia-Pacific and European countries and summarised in Table 5.2 and Table 5.3.

The annual mean TFP and GDP growth for Asia-Pacific were 0.861 per cent and 3.843 per cent, respectively, for the period 1990-2011, which was greater than the EU economies, which were 0.559 per cent and 2.538 per cent, respectively. However, for the period 1990-2011, the average contribution of ICT growth for Asia-Pacific was 0.482 per cent smaller than the average EU economy level of 0.844 per cent. Korea had the highest rate of TFP growth (2.571 per cent) among the Asian countries but the highest TFP growth in the EU was Iceland with 1.625 per cent. The mean contributions of labour and non-ICT capitals to GDP growth in Asia-Pacific countries were 0.418 per cent and 1.018 per cent, respectively, whereas for the EU countries they were 0.234 per cent and 0.574 per cent, respectively. Therefore, it seems that the higher growth rate of GDP in the Asia-Pacific countries than the EU were not sourced from ICT contribution due to the lower average ICT contribution in the Asia-Pacific countries.

Table 5-3. European growth decomposition

COUNTRY	EG(%)	L(%)	ICT(%)	non-ICT(%)	TFP(%)
SWEDEN	2.054	0.19	0.508	0.587	0.655
ICELAND	2.376	0.299	.	0.025	1.625
DENMARK	1.601	0.221	0.759	0.396	0.048
FINLAND	1.926	0.321	0.675	0.219	1.01
LUXEMBOURG	3.989	0.336	.	1.966	-0.113
SWITZERLAND	3.283	0.085	1.435	0.249	0.132
TOTAL	2.538	0.234	0.844	0.574	0.559

Source: Author's computation based on data from World Bank Development Indicators, 2013

Figures 5-1 and 5-2 show EG and TFP growth as well as the contribution of each capital; ICT, non-ICT and labour for Asia-Pacific and EU countries individually.

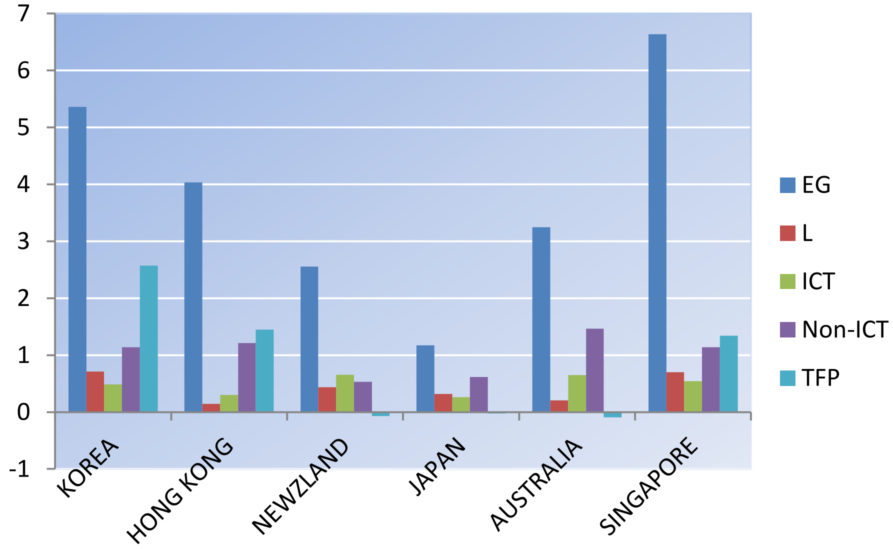

Figure 5-1.Growth decomposition for six top ranking of ICT
Source: World Bank Development Indicators, 1990-2011

However, from the two Figures, we can conclude that the Asia-Pacific countries are lagging behind the EU regarding ICT intensity and also in terms of their contribution of ICT capital to growth.

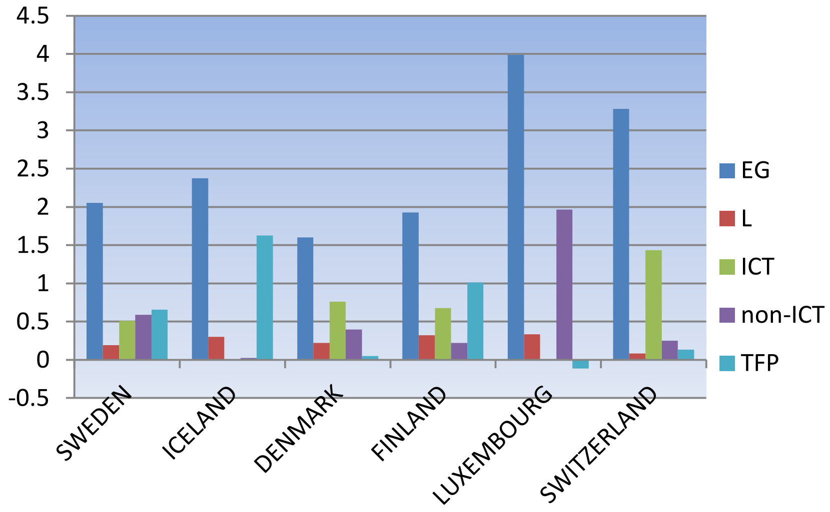

Figure 5-2.Growth decomposition for six top ranking of ICT
Source: World Bank Development Indicators, 1990-2011

Furthermore, the contribution of ICT-production to GDP growth is slightly lower in the Asia-Pacific countries than in the EU, owing to the reduced production share in ICT for Asia-Pacific. Generally, the Nordic countries (Denmark, Finland and Sweden) are identified by their relatively greater share for software, with considerable diffusion. However, this has not yet translated into substantial acceleration of growth for these countries. In particular, Finland is characterised by a robust growth of ICT capital as well as a significant contribution from ICT service runs to TFP and EG growth since it is a key ICT-producer in the EU (Aghion & Howitt, 1997). The figures for countries, such as Luxembourg, Iceland and Hong Kong, showed that despite their low ICT contribution, that higher growth of the economy was captured between other countries in each group.

Indeed not all dissimilarities between Asia-Pacific and the EU can be accounted for when considering ICT and TFP contributions to GDP growth under the hypothesis of lagging ICT diffusion. This fact implies that ICT improvement is not merely factor differences in productivity and GDP growth between the European and the Asia-Pacific countries but that ICT penetration could also play a key role. To sum up, from Tables 5-

2 and 5-3 it is apparent that ICT contribution to value added across two regional groups is not strongly correlated with the level of GDP growth and TFP growth.

5.3 Unit Root Tests for Asia-Pacific and European Countries

Before running the cointegration approaches, we have to identify the order of integration for each variable. One of the ways is to apply the panel unit root test of Im et al. (2003, hereinafter IPS). This analysis is limited compared to the tests by Levin et al. (2002) and Breitung (2000), which, usually, do not allow for heterogeneity in the autoregressive coefficient. On the other hand, in the aggregate level, we have added some additional variables to our model for more control. The first generation tests, such as Levin et al. (2002), Breitung (2000) and Hardi (2000), need to be tested on strongly balanced panels whereas the additional controlling variables in our new panels are not strongly balanced.

Nevertheless, the test suggested by IPS resolves Levin and Lin's serial correlation issue by presuming heterogeneity between units in a dynamic panel framework. The IPS test has the disadvantage of assuming that the cross-sections are independent. The equal assumption is done in all first-generation panel unit root tests. However, it is often mentioned in the literature that cross-section dependency may develop due to unobserved common factors, externalities, regional and macroeconomic linkages and unaccounted residual interdependence. Currently, the new panel unit root test presented by Pesaran (2007) has corrected the question of the dependency and correlation providing the prevalence of macroeconomic dynamics and linkages Therefore, we employed the IPS (1997), Fisher-type (1999) and Pesaran (2007) tests for the two regional group panels.

Table 5-4. Asia-Pacific and European countries, panel unit root tests

Variables	Asia-Pacific Countries			European Countries		
	Pesaran (2007) pescadf	Im, Pesaran & Shin(1997) IPS	Maddala & Wu (1999) Fisher-type	Pesaran (2007) Pescadf	Im, Pesaran & Shin(1997)IPS	Maddala & Wu (1999) Fisher-type
EG Level	-1.264(0.103)	-3.100* (0.001)	0.859(0.194)	-0.498 (0.309)	-2.655* 0.004)	-0.386 (0.650)
First-difference	-3.075*(0.001)	-8.764* (0.000)	7.357*(0.000)	-1.978*(0.024)	-9.937* 0.000)	2.636 * (0.004)
L Level	-1.177(0.120)	-4.466*(0.000)	-0.348 (0.636)	0.109 (0.543)	-1.892* (0.029)	-0.361 (0.641)
First-difference	-3.675(0.000)	-5.054*(0.000)	5.436*(0.000)	-3.322 (0.000)	-8.191* (0.000)	5.162* (0.000)
ICT Level	1.43**(0.076)	-0.910 (0.181)	-0.359 (0.640)	1.574 (0.942)	-2.368* (0.009)	-0.177 (0.570)
First-difference	-3.874*(0.000)	-5.005* (0.000)	1.684* (0.046)	-1.598**(0.055)	-4.998* (0.000)	8.541* (0.000)
Non-ICT Level	1.38**(0.084)	-0.077(0.469)	0.977 (0.164)	-0.456 (0.324)	-3.322*(0.000)	0.487 (0.313)
First-difference	-2.305*(0.011)	-4.888(0.000)	4.359*(0.000)	-4.001* (0.000)	-5.424*(0.000)	1.763* (0.039)
TFP Level	-0.482 (0.315)	-6.816* (0.000)	1.321** (0.093)	-0.792(0.214)	-4.271*(0.000)	0.879 (0.189)
First-difference	-2.428*(0.008)	-8.236* (0.000)	12.835*(0.000)	-1.833*(0.033)	-5.071*(0.000)	6.209*(0.000)
ICT-im Level	4.269 (1.000)	0.261 (0.603)	0.184(0.426)	-0.664 (0.254)	-0.109 (0.456)	3.725* (0.000)
First-difference	0.399 (0.655)	-3.889*(0.000)	2.750*(0.003)	-3.084* (0.001)	-3.769*(0.000)	16.332*(0.000)
PTR Level	0.46 (0.677)	-0.597 (0.275)	-0.588 (0.722)	0.885 (0.812)	0.368 (0.643)	-1.667 (0.952)
First-difference	-1.62**(0.053)	-5.456*(0.000)	5.499*(0.000)	-1.599**(0.055)	-5.802*(0.000)	1.843*(0.033)
PTN Level	-0.678(0.249)	-1.267(0.103)	-1.042(0.851)	-0.514 (0.304)	-0.669 (0.251)	0.894 (0.185)
First-difference	-2.302*(0.011)	-5.682*(0.000)	3.318*(0.001)	-2.296*(0.011)	-9.665*(0.000)	2.059*(0.019)
RDE Level	------	-------	0.194(0.423)	------	-------	-0.514(0.696)
First-difference	0.029 (0.512)	-2.761*(0.003)	9.446(0.000)	4.704 (1.000)	-------	14.950*(0.000)
TERIT Level	1.824 (0.966)	1.726(0.957)	-0.771(0.779)	5.233(1.000)	1.079 (0.859)	0.687(0.246)
First-difference	0.323 (0.627)	-1.654*(0.049)	2.602*(0.004)	0.459 (0.677)	-2.686*(0.003)	1.775*(0.038)
HT Level	-0.312 (0.377)	1.432(0.924)	-0.893 (0.813)	1.095 (0.863)	0.646 (0.740)	0.362 (0.358)
First-difference	-4.556*(0.000)	-8.313*(0.000)	2.724*(0.003)	-1.980*(0.024)	-3.737*(0.000)	8.364*(0.000)
UPL Level	-0.367 (0.357)	-0.979(0.163)	1.263 (0.103)	0.112 (0.545)	-1.441(0.075)	-0.118(0.547)
First-difference	-2.567*(0.005)	-4.894*(0.000)	2.691*(0.004)	-2.399*(0.008)	-2.731*(0.003)	17.925*(0.000)
EXP Level	-0.798(0.212)	-0.819 (0.206)	-1.799(0.964)	0.840 (0.799)	-0.868(0.192)	0.684(0.247)
First-difference	-2.541*(0.006)	-5.229*(0.000)	2.681*(0.004)	-0.306(0.380)	-5.218*(0.000)	4.913*(0.000)
IMP Level	0.070 (0.528)	-0.788(0.215)	-2.081 (0.981)	1.147(0.874)	0.444 (0.671)	-0.716 (0.763)
First-difference	-1.930*(0.027)	-6.359*(0.000)	4.384*(0.000)	-2.039*(0.021)	-3.388*(0.000)	4.244*(0.000)

Notes: The null hypothesis is that the series is a unit-root process except the Hadri(2000) test.
P-values are given in parentheses.

Probabilities for the Fisher-type tests are computed using an asymptotic Chi-square distribution. All the other tests are assumed to be asymptotic normal. The lag length is selected using the Modified Schwarz Information Criteria.
* Indicates the parameters are significant at the 5% level.
**Indicates the parameters are significant at the 10% level.
[a]all of values are z(t-bar).

Source: Author's calculation, 2013

The 'first generation' of panel data integration tests, such as IPS (2003) and Fisher (1999), assume cross-sectional independence among panel units (except for common time effects), while the ''second-generation'' of panel data unit root tests, such as Pesaran (2007), control for common time effects as well as more general forms of cross-sectional dependency. The results of the Fisher-type (1999), IPS (2003) and Pesaran (2007) panel unit root tests are presented in Tables 4-5 for both the Asia-Pacific and EU countries. For all fourteen variables, the null hypotheses of the unit roots is not rejected at level. These outcomes robustly indicate that all the variables are non-stationary in level but become stationary in first-differences at the 10 per cent and 5 per cent significance levels.

5.4 Panel Cointegration Tests for Asia-Pacific and European Countries

As indicated, the fundamental idea behind cointegration is to examine whether linear combinations of variables are individually non-stationary or stationary. The Kao (1999) residual based test was used to perform ADF stationary test on the residuals of the first estimated model with all variables. There is a restriction for the number of variables to handle the Pedroni (2004) cointegrating test. Therefore, in this research, we will only employ the Kao (1999) cointegration test for the two regional groups of countries. Table 5-5 presents the Kao (1999) test results.

Table 5-5. The Kao residual cointegration test results

		Lag [a]	t-statistic	Probability
Asia-Pacific Countries	ADF	3	3.3168*	0.0005
European Countries	ADF	3	-2.0757*	0.0190

Note: Null Hypothesis: No cointegration,
[a] lag selection using Parzen kernel,
*Indicate that the parameters are significant at the 5% level.

Source: Author, 2013

According to the results, all 14 variables in the two group panels are cointegrated. As in the industrial level test, we have disregarded the controlling variables and only performed the Pedroni and Kao test on EG, ICT, non-ICT, L and TFP for the aggregate level and we have also found cointegration. Therefore, we can apply the error correction model due to the causality test.

5.5 Panel Granger Causality Results for Asia-Pacific and European Countries

The growth decomposition analysis shows that most of the Asian countries enjoy lower rates of ICT adoption in comparison to their possible levels of advancement (GDP/capita) and competitiveness (World Competitiveness Index). Disparities in ICT diffusion are rather massive and while noted in Section 5.2 a significant ‘digital divide’ is present even between the Asia-Pacific and EU countries. It is clear from Tables 5-6 and 5-7 that ICT contribution across the two regional groups of countries is not closely related to the level of GDP and TFP growth. Consequently, the effects of other efficient factors, such as ICT adoption and GDP growth, need to be controlled before more definite opinions are drawn on the causal relationship among all these variables.

Table 5-6. Panel causality test results, Asia-Pacific countries

Dependent Variable	*Source of Causation (independent variable)*						*Estimation Method , Based on Hausman Test*
	Short Run					*Long Run*	
	ΔEG	ΔL	ΔICT	Δnon-ICT	ΔTFP	ECT	
ΔEG	-----	-0.0571 (0.934)	5.6567 (0.104)	0.5863** (0.090)	-0.1251 (0.575)	-0.8810* (0.000)	PMG
ΔL	-0.0378* (0.000)	-------	-0.6176* (0.000)	-0.0796 (0.386)	0.0145 (0.154)	-0.7241* (0.000)	DFE
ΔICT	-0.0103* (0.050)	0.0337* (0.050)	------	-0.0396 (0.574)	0.0023 (0.729)	-0.1451* (0.003)	DFE
Δnon-ICT	-0.0388* (0.000)	-0.0478 (0.639)	-0.1234 (0.258)	-------	0.0063 (0.556)	-0.2072* (0.000)	DFE
ΔTFP	-0.0173 (0.838)	-0.4492 (0.276)	-0.4277 (0.806)	-0.4449 (0.724)	--------	-1.1653* (0.000)	DFE

Note: The reported values in parentheses are the p-values of the F-test.
*indicates significant at the 5% level, **indicates significant at 10% level.

Source: Author, 2013

Based on the PMG estimator results in Tables 5-6 and 5-7, ICT did not appear as an effective factor on GDP growth in the Asia-Pacific countries or even the EU countries between 1990 and 2011. However, the ICT return in the Asia-Pacific countries (5.656 per cent) is higher than in the EU counties (1.437per cent); however, for both regional groups of countries, there is a long run significant causality relationship running from ICT, L, non-ICT and TFP to GDP growth. In contrast to the results of Hwan-Joo et al. (2009) for 29 countries, non-ICT contribution has a causal relationship with economic growth and plays a key role in the growth process. The ICT contribution does not have a strong interdependent relationship with economic growth across the Asia-Pacific and EU countries between 1990 and 2011.

Table 5-7. Panel causality test results, EU countries

Dependent Variable	*Source of Causation (independent variable)*						*Estimation Method , Based on Hausman Test*
	Short Run					*Long Run*	
	ΔEG	ΔL	ΔICT	Δnon-ICT	ΔTFP	ECT	
ΔEG	-----	22.2106 (0.287)	1.4379 (0.215)	2.2419** (0.052)	0.3738 (0.181)	-0.4511* (0.036)	PMG
ΔL	-0.01360 (0.630)	-------	-0.2970 (0.260)	-0.3514 (0.215)	-0.0198 (0.111)	-0.5209** (0.086)	MG
ΔICT	-0.0192* (0.673)	3.7241* (0.311)	------	0.3071 (0.677)	0.0551 (0.664)	-0.1439 (0.189)	PMG
Δnon-ICT	-0.0335* (0.018)	0.0235 (0.575)	-0.0168 (0.256)	-------	0.0051 (0.838)	-0.3332* (0.000)	DFE
ΔTFP	0.4524* (0.003)	-1.6360 (0.131)	-1.7473** (0.065)	-0.9525** (0.073)	--------	-0.3713* (0.016)	PMG

Note: The reported values in parentheses are the p-values of the F-test.
*indicates significant at the 5% level, **indicates significant at the 10% level.

Source: Author, 2013

With respect to TFP, ICT has a negative and significant effect in the EU countries (-1.747 per cent), but this is not true for the Asia-Pacific countries. The negative effects of ICT on TFP is proof of the slow acceleration of TFP in the EU countries. This is in line with numerous studies that investigated the productivity paradox in EU countries. An important point from the two tables is that the short run source of growth in the two regional group of countries is non-ICT capital with positive and significant effects on GDP growth (2.586 per cent, 2.241 per cent). Therefore, countries are able to capture higher GDP growth with more investment in non-ICT for achieving a large potential for growth.

Table 5-8. Panel industries direction of causality in short run and long run, Asia-Pacific

Short run causality		*Long run causality*	
Direction of Causality	*Wald F-test*	*Direction of Causality*	*Wald F-test*
ΔEG ---------→ ΔL	(0.507) (0.000)*	EG ←-------→ L	(0.000)* (0.000)*
ΔEG ---------→ ΔICT	(0.001)* (0.050)*	EG ←-------→ ICT	(0.000)* (0.003)*
ΔEG ←-------→ Δnon-ICT	(0.012)* (0.000)*	EG ←-------→ non-ICT	(0.000)* (0.000)*
ΔEG No causality ΔTFP	(0.280) (0.838)	EG ←-------→ TFP	(0.000)* (0.000)*
ΔL ←-------→ ΔICT	(0.000)* (0.050)*	L ←-------→ ICT	(0.000)* (0.003)*
ΔL No causality Δnon-ICT	(0.386) (0.639)	L ←-------→ non-ICT	(0.000)* (0.000)*
ΔL No causality ΔTFP	(0.154) (0.276)	L ←-------→ TFP	(0.000)* (0.000)*
ΔICT No causality Δnon-ICT	(0.574) (0.258)	ICT ←-------→ non-ICT	(0.000)* (0.003)*
ΔICT No causality ΔTFP	(0.729) (0.806)	ICT ←-------→ TFP	(0.000)* (0.003)*
Δnon-ICT No causality ΔTFP	(0.724) (0.556)	non-ICT ←-------→ TFP	(0.000)* (0.000)*

Note: The reported values in parentheses are the p-values of the F-test.
*indicates significant at the 5% level, **indicates significant at the 10% level.

Source: Author, 2013

Table 5-8 shows long run bidirectional causality between GDP growth and contribution of ICT, L, non-ICT and TFP growth for Asia-Pacific countries, while there is only unidirectional causality running from ICT to GDP and TFP growth in the EU panel.

For EU countries in the short run, there is no causality relationship between ICT capital and GDP growth, but, for the Asia-Pacific countries, unidirectional causality runs from economic growth to ICT contribution. Therefore, short run ICT investment policies do not have any impact on growth for the two regional groups of countries; it needs to switch to long run ICT investment policies for both Asia Pacific and the EU. Indeed, in the short run, the high growth rate of GDP in countries like Singapore and Korea increases the ICT spillover effects on TFP to sustain economic growth.

Table 5-9. Panel industries direction of causality in short run and long run, EU

Short run causality		*Long run causality*	
Direction of Causality	*Wald F-test*	*Direction of Causality*	*Wald F-test*
ΔEG No causality ΔL	(0.287) (0.630)	EG ←-------→ L	(0.036)* (0.086)**
ΔEG No causality ΔICT	(0.215) (0.673)	EG ←-------- ICT	(0.036)* (0.189)
ΔEG ←-------→ Δnon-ICT	(0.052)** (0.018)*	EG ←-------→ non-ICT	(0.036)* (0.000)*
ΔEG ←-------- ΔTFP	(0.181) (0.003)*	EG ←-------→ TFP	(0.036)* (0.016)*
ΔL No causality ΔICT	(0.260) (0.311)	L ←-------- ICT	(0.086)** (0.189)
ΔL No causality Δnon-ICT	(0.215) (0.575)	L ←-------→ non-ICT	(0.086)** (0.000)*
ΔL No causality ΔTFP	(0.664) (0.131)	L ←-------→ TFP	(0.086)** (0.016)*
ΔICT No causality Δnon-ICT	(0.677) (0.256)	ICT --------→ non-ICT	(0.189) (0.000)*
ΔICT --------→ ΔTFP	(0.664) (0.065)**	ICT --------→ TFP	(0.189) (0.016)*
Δnon-ICT --------→ ΔTFP	(0.838) (0.073)**	non-ICT ←-------→ TFP	(0.016)* (0.000)*

Note: The reported values in parentheses are the p-values of the F-test.
*indicates significant at the 5% level, **indicates significant at the 10% level.

Source: Author, 2013

5.6 Panel Long run Relationship by Using System GMM for Asia-Pacific and European Countries

In this part of the research, we add some new variables for two main reasons:

1. Due to the limitation of the industrial level data, employment of a more sophisticated model was not possible, which would essentially control the impact of other variables. Several factors were identified by the studies, which are strongly correlated with the levels of ICT growth including education levels, trend variables, GDP growth and employment share in the service sector. In addition, it is apparent from Tables 5-8 and 5-9 that ICT contribution across two regional groups of countries is not strongly correlated with the level of GDP growth and TFP. Consequently, the impact of the other effective factors of GDP growth should be controlled by employing more related factors in the model like education, innovation and trade.

2. According to the 'endogenous growth model', innovation is a medium for technological spillovers that allows less developed countries to catch up with highly developed countries. On the other hand, ICT capital seems to have the characteristics of

both forms of capital, traditional forms of capital as a production technology and knowledge capital in its informational nature (Dedrick, Gurbaxani, & Kraemer, 2003). An essential characteristic of the debate under the existence of ICT spillover is whether the ICT capital stock may also boost economic growth through positive spillover effects on TFP, if ICT capital is like knowledge capital. The sources for total factor productivity (TFP) growth may be relatively different over time and across countries, but technological change and innovation have been mainly acknowledged as determinants of TFP growth, and ICT has been considered as the major form of technological change in recent decades (Madden & Savage, 2000). Thus, if we add new variables that are related to the spillover effects of ICT, the significance of the model should increase.

The descriptive list of variables, which is using the estimation in the long run model, has been mentioned in Table 1 of the study. Moreover, it should be remembered that GMM estimators are particularly practical for panel data with comparatively small time length (T), in comparison to the number (N) of cross-sections (Roodman, 2006). In contrast, as T becomes larger, misleading and inconsistent coefficient estimates could be produced by the GMM estimator unless and until the slope coefficients are the same throughout the cross-sections (Pesaran & Smith, 1995). Through the estimation of separate regression of two time groups, the problem of a relatively large time dimension (N = 26, T = 21) has been addressed for the sub-periods of 1980-1990 and 1990-2000. As justified, it has enabled us to search for the varying effects of ICTs across time. Furthermore, the start and end points of the periods have been selected in such a way that the economy is at similar stages of the business cycle. This has been preferred due to the elimination of the impact of business cyclical factors on the output measures.

In this research, System GMM is selected in the industrial level panel and first-difference GMM for the aggregate level. However, a couple of crucial issues need to be addressed regarding employing System GMM. First, since System GMM uses added instruments compared to the difference GMM it might not be proper to apply System GMM with a dataset comprising a small number of countries (Mileva, 2007). From the methodology part, aggregate panel data are estimated across six countries (N=6) in 11 sub periods (T=11) for each group of countries. Therefore, we are going to use first-difference GMM for the aggregate level part due to the small number of countries and System GMM for the industrial level part with large cross-sectional data (N=21, T=17).

Arrelano and Bond (1991) GMM regressions are carried out based on equation (15), after applying the heteroscedasticity robust one-step estimator, while setting out individual regressions for both groups of Asia-Pacific and EU countries. Table 5-10 presents the estimation outputs for the sample of the Asia-Pacific and EU countries individually per decade (columns 1 and 2, 3 and 4). In the columns for the two regions, we intend to verify the differential impacts before and after 2000 to estimate the greater ICT growth contribution in the United States between 1996 and 1999 and we need to test whether it supports the Asia-Pacific and EU panels.

From the presented estimates of Table 5-10, it appears that the effects of non-ICT on the Asia-Pacific countries growth were highly positive and significant over two periods, while employment capital seems to be correlated negatively and significantly with output growth. Similar estimation results are reported for the EU (columns 3, 4); both L and non-ICT were highly positive and significant over two periods, with the exception of the first period for non-ICT capital, the impact of which reduces.

TFP growth has emerged as having a significant and positive effect on GDP growth for both regions during the two periods with a difference in magnitude that shows that the positive effect for Asia-Pacific countries in the second period is higher than its first period but for the EU, the growth of TFP in the first period is more effective for GDP growth. The overall return to TFP growth in the EU is higher than for the Asia-Pacific countries.

Table 5-10. Long run panel data estimators for Asian and European countries

Independent Variables	*Dependent variable:EG*			
	Difference GMM Estimates, one step, Asian countries		*Difference GMM Estimates, one step, European countries*	
	1990-2000	2001-2011	1990-2000	2001-2011
L	-2.0647* (0.000)	-4.7657** (0.083)	1.8805* (0.000)	0.8415* (0.000)
ICT	5.2146* (0.000)	-5.9153 (0.378)	-0.9477* (0.000)	1.2236* (0.000)
NON-ICT	8.4523* (0.000)	4.0039** (0.081)	-9.1465* (0.000)	1.0359* (0.007)
TFP	0.9699* (0.000)	1.0373* (0.027)	2.8129* (0.000)	0.7356* (0.000)
ICT-IM	0.8637* (0.000)	0.0728 (0.431)	-3.1629* (0.000)	1.1440* (0.000)
PTN	-0.0006* (0.022)	-0.0004 (0.298)	0.0034* (0.000)	0.0209* (0.000)
PTR	-0.0002* (0.044)	7.31E-05 (0.166)	-0.0126* (0.000)	0.0024* (0.000)
TERIT	0.0980* (0.044)	-0.1479** (0.089)	-0.1948* (0.000)	-0.0459* (0.012)
HT	0.0740 (0.730)	-0.0359 (0.915)	1.5442* (0.000)	-0.2856* (0.001)
UPL	-1.2521* (0.013)	-1.7218** (0.084)	-3.006* (0.000)	-0.2989 (0.422)
EXP	-0.2234 (0.272)	-0.2804 (0.488)	0.0710* (0.032)	0.4223* (0.000)
IMP	0.5442 (0.106)	0.2052 (0.546)	-0.7907* (0.000)	-.0439* (0.584)
Obs	15	18	13	14
countries	6	6	6	6
Wald test	46.28	305.04	545.23	25.69
Sargan test(p-value)[a]	0.005	0.126	0.000	0.008
Hansen test (p-value)[b]	1.000	1.000	1.000	1.000
Serial correlation test AR(1) (p-value)[c]	0.108	0.088	0.103	0.126
Serial correlation test AR(2) (p-value)[c]	0.300	0.101	0.103	0.096
Serial correlation test AR(3) (p-value)[d]	0.187	0.899	0.103	0.171

a. Sargan test is evaluating overidentifying restrictions in Ivs. The null hypothesis is that the instruments used in the regression are valid.
b. Hansen test is evaluating overidentifying restrictions in GMM. The null hypothesis is that the instruments used in the regression are exogenous.
c. d. The null hypothesis is that the error in the first-difference regression exhibit no first or second order serial correlation.
The values in parentheses denote the significance level for rejection.
*Indicate that the parameters are significant at the 5% level.
**Indicate that the parameters are significant at the 10% level.

Source: Author, 2013

The ICT growth impact only seems to have increased significantly in magnitude during the 1990s and 2000s for the EU countries. While in the Asia-Pacific countries, ICT lost effect in both magnitude and significance on GDP growth during the 2000s. This can be interpreted as ICT was the engine of growth in the 1990s for the Asia-Pacific countries, whereas it had the same role in growth for the EU economy in most cases through to the 2000s.

According to the Asia-Pacific results, for 1990-2000, the ICT effect increased considerably, presenting a highly positive and significant relationship with output growth that was experienced in the second part of 1995. This proof demonstrates the stylised facts shown in the literature, that the ICT growth contribution was enhanced extensively throughout 1995, especially in Asia, similar to the US economy but unlike the EU countries.

Regarding the EU industries, the total ICT growth contribution is significant in the two periods (columns 3 and 4). In the 2000s, its effect is substantially increased in magnitude and significance compared to 1990-2000. All this information shows that ICT should be able to play a significant role in improving growth among the EU countries, via its speedier capital accumulation. In spite of this, the pertinent worth of ICT increased significantly through the second period from -0.94 to 1.22, whereas for Asia-Pacific it dropped from 5.214 to -5.915. In general, it seems that when comparing the results of two regional groups of countries, the impact of ICT is higher in the EU economy than for the Asia-Pacific countries not only from the direct effects of ICT as capital but also through TFP growth by positive spillover effects.

Considering the other explanatory variables for controlling the spillover effects of ICT independently from TFP, it is interesting to know that most of them are only robustly significant in the EU and Asia-Pacific countries during the first period. For example, the coefficient of patent application for residents and non-residents and school enrolment

(PTN, PTR, TERIT) are statistically significant at the 5% significance level in columns (1) and (3) but PTR and PTN are insignificant for the second period of Asia-Pacific countries. In addition, the magnitude of this coefficient is higher in the first period for Asia-Pacific but it is higher in the second period in the EU countries. The significance of the education and patent variables suggest that educational and patent attainments are important determinants of the ICT contribution to growth. The coefficient is negative but higher in the EU than Asia-Pacific, which suggests that the impact of education and patent application were somewhat accelerated and more effective in the EU economies

Similar patterns are also observed for unemployment, ICT import and high-technology export and import goods and services (UPL, ICT-IM, HT, EXP, and IMP). HT, EXP, and IMP are totally insignificant for the Asia-Pacific countries while they have significant effects in the EU for both periods together with the expected signs. Since the signs for the variables for the Asia-Pacific countries are not as expected in the findings, one should bear in mind the drawback of the variables of export and import, which did not adequately capture the openness of the Asia-Pacific economies. The outcomes indicate that the openness provides some negative effect on ICT contribution to output growth. However, this effect is not statistically significant.

The unemployment rate has a negative and significant impact on growth for the two regional groups of countries except for the second period of the EU economies. ICT imports emerged as a significant factor for all the countries except the second period for the Asia-Pacific countries. The results suggest that education, openness and high quality patents are supposed to be among the main determining factors of the difference in ICT spillover impacts to output growth across economies. Along with these elements, it is predicted that ICT and technology trade is usually an essential determinant of the ICT spillover impact on growth because countries with a higher level of trade may gain large benefits from the Internet, for which online trade is the dominant way of export and import (Vu, 2005). Furthermore, it is shown that knowledge spillovers have been an important contributing factor behind the TFP convergence among the countries over the whole period. Knowledge spillovers from ICT use in education to ICT use somewhere else, provide several fields for policy involvement by developing the ‘effective computer literacy spillover potential’ of proper education, thereby positively affecting the overall growth performance.

To sum up, it seems that the spillover effects of ICT between 1990 and 2000 emerged more than between 2001 and 2011 and more strongly in the EU than for Asia-Pacific countries over two decades. Most of these results expressed that boosting these main determinants is an efficient method to foster ICT diffusion and its effect on economic growth.

As mentioned in the earlier sections, the constancy of the GMM estimator is dependent on the validity of the instruments employed in the GMM regression along with the absence of the second-order serial correlation in the error term. Table 5-10 documents the outputs of the Hansen J test and of the second and third order serial correlation test. For all of the conditions, the Hansen J test does not reject the null hypothesis that the instruments applied in the regressions are valid. Moreover, the test that checks for serial correlation does not reject its null hypothesis, indicating that the error term fails to manifest serial correlation in the first and second order correlation.

5.7 Justification of insignificant effects of ICT on GDP growth in EU and Asia-Pacific countries

Tables 5-6 and 5-7 present the results for the EU and Asia-Pacific countries, respectively. It is indicated in the Hausman test that proof of the equality among the PMG, DFE and MG estimates is not rejected and it is shown that common long run elasticity is accepted by the data. Consequently, our estimated results are based on the

PMG estimators, which are estimated as maximum likelihood, while the Schwartz Bayesian Criterion is used to choose the appropriate lag length.

The Asia-Pacific econometric results are reported in the first row of Table 5-6. With respect to the ICT impact on output growth, we can see that the estimated short run effect for the period 1990-2011 is positive and insignificant. Particularly, the implication of its magnitude is that an increase of 1 per cent in ICT capital increases the output growth by 5.66 per cent. As compared to the System GMM estimates, the reported long run coefficient's magnitude is comparatively more. The insignificant effect of ICT on GDP growth is positive in 1990-2000 and negative in 2001-2011 for Asia-Pacific, which is inverse to that of the EU, and which may have different reasons listed as follows:

1. In the GMM results, we noticed that the ICT capital's impact is insignificantly negative between 2001 and 2011. One of the most important criteria of ICT in society is rapid progress and development during the short-term. In theory, while a new severe innovation, such as new equipment of ICT arrives, economies suffer from primary economic loss; consequently, it emerges in a kind of capital obsolescence that would decrease GDP growth (Helpman & Trajtenberg, 1998; Aghion & Howitt, 1998).

2. Empirically, evidence has been presented in previous research regarding the declining effect of ICT capital on productivity in the economy. The negative long run impact of ICT capital is quite doubtful, so this finding is attributed to factors related to parameter heterogeneity throughout countries and model uncertainty, or certain outlier impacts that are currently considered as the main constraints in the modern empirical growth literature (Striroh, 2002).

3. Similar ambiguities could be found in the GMM results. For instance, with regards to FDI (Foreign Direct Investment), it is shown by Blomstrom et al. (1996) that there is a decrease in the significance of the fixed investment variable when total capital is split to

non-FDI and FDI investment. Therefore, in this research, the capital factor is divided into non-ICT and ICT capital. It could be possible that the qualitative nature of other forms of capital, similar to ICT, is more impressive than the common augmentation of fixed capital stocks. It can be pointed out that during the 2000s, the importance of non-ICT capital declines when the total capital is distributed in non-ICT and ICT for EU and Asia-Pacific countries. This interpretation can be true for the PMG results for Asia-Pacific countries as well.

4. Despite the insignificant effects of ICT in the short run findings reported by PMG for both periods, the overall contribution of ICT on growth is significant and positive (columns 3 and 4) in EU countries. In the 2000s, as compared to the 1990s, there seems to be a substantial increase in the magnitude of its impact and the sign is also changed to positive. It is suggested by the results that through faster accumulation of capital, ICT can have a pivotal role in the enhancement of growth amongst the member countries of the EU. During the 2000s, there was a significant drop in the relative importance of ICT in the Asia-Pacific countries (column 2), while it increased from -0.94 to 1.22 in the EU. Generally, when the results of Tables 5-10 are compared, the impact of ICT is lower in the economy of the EU relative to the economy of Asia-Pacific, an outcome that was discussed in Section 5.6 and presented as a stylized fact.

5. In Asia-Pacific countries, such as Japan and Korea, during the 1990s a burst of productivity in the industries producing ICT equipment (computer hardware, software and telecommunications) led to a fall in the relative prices of ICTs, thereby increasing investment in ICT assets and capital-deepening across the whole economy. Therefore, ICT had a considerably significant and positive effect on the EG during the 1990s. In contrast, most of the literature attributes the European slow-down in productivity growth to the lag in ICT adoption by the ICT-using sector after 1995. Factors related to

national regulations may play a role in explaining the slow reorganisation of European firms around the new technology.

6. After 2007, the economic crisis drew a different picture in the Asia-Pacific and EU economies, with negative rates of GDP growth in both Asia-Pacific and the European countries. The average drop in GDP in the EU was slower than for the Asia-Pacific countries; thus, in the Asia-Pacific economies, adjustment to the crisis mainly occurred in the TFP and resulted in a dramatic decrease in the ICT-producing sector, whereas, in Europe, TFP losses were smaller and the adjustment occurred through a decrease in labour productivity. Nevertheless, labour quality and ICT investment continued to provide a positive contribution to growth (Van Ark, 2010).

7. The findings in this research suggest that the Asia-Pacific countries might benefit more from ICT than the countries in Europe. The GMM results revealed significant and positive returns from ICT capital that were larger in magnitude for the Asia-Pacific countries than the EU countries in the given sample. In this study, this gap is attributed to the absence of complementary investment as well as the low level of ICT investment in the Asia-Pacific countries. To obtain the productivity from ICT investment, complementary investment is a prerequisite, which includes knowledge-based structures, human capital and infrastructure, which, although available in the EU, are mostly unavailable in developing countries. Therefore, according to the causality findings of the research, economic growth is one of the sources of increasing ICT in these countries.

8. Complementary investments in countries have played an important role in reaping the full benefits of ICT. After sufficient complementary investments are developed, the new GPT spreads among the sectors, and, as such, the economy passes through the productivity paradox phase in which output growth and TFP accelerates. Furthermore, there is an argument that during the initial stage a creative destruction pattern emerges,

in which an initial fall in the growth of the GDP can be caused by capital obsolescence. In particular, if it were assumed that technological change is brought about by a rapid rate of capital, this would bring about the deskilling of human capital and the rapid rate of capital obsolescence, which, in turn, would lower the growth of GDP.

With regards to the EU results, the PMG long run estimators confirm the results of the System GMM estimates, which are reported in Table 5-10. In the short run, ICT's impact on output growth is insignificant and positive. For the EU, it seems that the significance and magnitude of the long run impact of ICT is lower relative to Asia-Pacific. This evidence is in line with the theoretical prediction, which states that there is an expectation of time lag in the effects of ICT. Consequently, the countries that lead in the implementation of ICT technology are expected to have higher returns from ICT. This means that the adoption of ICT technology in the EU takes a longer time than in the Asia-Pacific countries

In the 2000s, the impact of ICT was considerable, which indicates a significant and a highly positive relationship with the growth of output, which is essentially understood from the GMM results for the EU. This proof settles the stylized facts in Table 5-10 and discussed in Section 5.6, in that there was substantial improvement in the growth contribution of ICT during the second period of the EU economy.

All four Asian Dragons – Taiwan, Hong Kong, South Korea and Singapore – heavily invested in the sector of telecommunications, and, consequently, earned enormous benefits in the form of increasing exports. The Japanese pattern was not followed by them, instead, a better developmental model was found, which was appropriate for their particular economic requirements. Their economies were opened up to foreign participation by way of promoting the transfer of technology and using it to their maximum advantage for the formation of skills. In detail, the achievement of these countries has brought about a change in global production trends, such as a high percentage of ICT-production in terms of semiconductors, which are currently manufactured on their shores. Many niches have been established by the electronic products of NIEs in the global markets through their own technological progress. Although they are not a major threat to the American and Japanese ICT companies (excluding the field of semiconductors) due to the absence of substantial investment in research and development for simple sciences and also because of the shortage in capital, they persistently sell considerably well in a globalized world.

In recent months, other than South Korea, all the other Asian Dragons have demonstrated their capability of eluding the worst part of the financial crises that has gripped most of the Asia-Pacific region. Initial signs of recovery in South Korea, have already started to become apparent as foreign investors have again started to pour capital into the South Korean economy. For instance, despite the emerging competition, with US$40 billion market capitalisation, SingTel is the most efficient telecommunication company in Asia.

South Korea was connected to the liberalisation bandwagon from 1991, as it recognised that market and technological externalities attract foreign investors and benefit the corporate sector. This is because, in 1991, there was a change in South Korea's Telecommunications Business Law for the privatisation of its PTT, which is now known as Korea Telecom (KT). Korea's mobile communications sector was also privatised to form Korea Mobile Telecommunications, and, after further commercialisation, it became SKT Mobile. Korea has produced new innovations in the telecommunications sector with the invention of CDMA by Samsung for cellular telephones.Hong Kong's cellular telephone sector has a continuous growth at 15 per cent annually with cellular services enjoying a high penetration rate. Historically, Hong Kong's principal supplier of equipment produces Cable and Wireless (C&W) services.

To summarise, the above reasons demonstrate that the continued privatisation and liberalisation in the Asian Dragon's telecommunications sector will ensure that, despite the global economic crisis, continuous ICT convergence will be experienced by these countries as a powerful force in their continuous development.

CHAPTER 6: CONCLUSION, POLICY IMPLICATIONS, AND FURTHER RESEARCH

6.1 Introduction

The accumulation of Information Communication Technology (ICT) capital having a positive influence on the productivity growth and rising income in various countries has attracted much debate among economists in recent years.

On the one hand, it is claimed that the improvement of ICT has a positive short-lived effect but no long run effect on growth. On the other hand, it is argued that ICT has provided important changes in the economy due to durable developments in growth prediction. ICT is a sort of technology with wide access to numerous parts and has supplied complementary goods and services to further enhance productivity through specialisation and economies of scale.

Empirical analysis of economic growth and productivity has brought to light three distinct effects of ICT. First, ICT has attracted investment, which, in itself, has contributed to capital deepening, and, as such, helped in raising productivity and growth in Gross Domestic Product (GDP). Second, rapid technological progress in the production of ICT goods and services has also contributed to the growth in the efficiency of capital and labour. This also means that total factor productivity (TFP) in the ICT-producing sector brings greater returns to the ICT-producing sector. Third, greater use of ICT in the economy can help business firms in the enhancement of their overall efficiency. This means that increasing TFP may bring higher returns to ICT-using sectors.

The review of ICT literature has proved that, since 1990, ICT diffusion in Europe has followed a different pattern relative to Asian countries. These differences may start with a quick improvement of computing equipment in offices, which is followed by a surge in communication equipment, thus increasing investment in software services, particularly in such Asian countries like Japan and Korea. The ICT development ranking of countries was overlooked in the discussion of the ICT effects. For these reasons, we have covered the above three effects of ICT on the economic growth of 12 top ranked ICT developed countries in Asia-Pacific and the European zone over the period 1990 to 2011. This study also finds differences in country performances in the two regions.

This study has identified the causal relationship between the contribution made by ICT and TFP to economic growth by using panel data for 12 Asia-Pacific and European countries over the period 1990 to 2011. Furthermore, ICT has played different growth roles in the form of ICT-producing and ICT-using industries over 1990 to 2007. We have also examined the long-term impact of ICT and capture the long run equilibrium relationship among GDP growth, contribution of ICT and non-ICT labour force, TFP and other variables. Our main findings can be classified into two major results. First, and indeed the main result, relates to the industrial level data of countries like Japan, Finland, Sweden, Denmark and Australia, which considered the ICT effects on growth of 21 industries for each country. Second, is the aggregate level data that looked at 12 ICT developed countries in Asia-Pacific and Europe.

The average ICT contribution to the economic growth in these countries has been between 0.4 per cent and 0.5 per cent per year depending on the country. During the 1990s, the ICT contribution rose from 0.3 to 1.16 percentage points per year while during the 2000s this contribution fluctuated between 0.23 to 0.93 percentage points per year. Our research shows that despite the differences among countries, the EU countries have not been alone in benefiting from the positive effects of ICT capital investment on economic growth while they did not experience an acceleration of these effects. ICT diffusion plays a key role and depends on the right framework conditions, not necessarily on the existence of an ICT-producing sector (Colecchia & Schreyer, 2002).

6.2 Main Findings of Industrial Level Data

6.2.1 **Japan**

According to the growth decomposition analysis of the previous chapter, Japan suffered economic stagnation through the last period due to three factors that played a role in the growth slump. The deceleration in TFP accounted for 8 per cent of the sluggish performance, whereas the negative contribution of labour and the fall in the contribution of ICT input growth each accounted for 44 per cent and 10 per cent of the sluggish performance, respectively. In line with the results of Fukao et al. (2009), the EU KLEMS statistics also show in detail that the ICT contribution rate dropped by an average of 0.26 per cent, from 0.43 per cent to 0.30 per cent from 1990 to 2007 in Japan.

Considering the ICT effect on output growth, we notice that the estimated short run impact for the period 1990-2007 is negative and insignificant. Notably, its magnitude means that a 1 per cent rise in ICT capital results in a 0.098 per cent decrease in output growth among 21 industries. In Japan, ICT is only considered as significant and positive capital in six industries, which include transport, storage, post and telecommunication sectors. We additionally note that the results of non-ICT capital are significantly positive. Theoretically, whenever a highly upgraded modernisation (such as ICT) emerges, the economy as a whole does experience preliminary economic loss (Dimelis & Papaioannou, 2011). For this reason, we want to test the complementary hypothesis between ICT and non-ICT capital, which includes their interaction term (ICT_non-ICT) like a different regressor in the long run relationship. The outcomes prove that there is no significant complementary impact between ICT and non-ICT capital. As a result, the Japanese economy has not considered ICT as a major modernisation tool since non-ICT reported a positive significant effect. In line with Helpman and Trajtenberg (1998), the economy would have initial losses attributed to the negative significant effect of non-ICT capital.

With respect to the TFP results, the impact of ICT on TFP is negative (-0.157) and insignificant in the short run while non-ICT and labour are significant and negative (0.386, -0.284). This evidence is in line with the theoretical expectation that the impact of ICT on TFP at the industrial level is expected with a time lag but significant in the long run. Empirically, Stiroh (2002a) provided proof of a reduction in the impact on productivity of ICT capital in the EU economy. Similar proof has been presented by O'Mahony and Vecchi (2005) for an industry level research that addresses the US and United Kingdom sectors.

The causality results for Japan have been reported as negative and statistically significant coefficients of the Error Correction Term (ECT) implying that any divergence of output growth from the long run equilibrium level causes a change in the opposite direction. Moreover, the long run bidirectional Granger causality is shown running real GDP growth to the contribution of L, ICT, non-ICT, and TFP growth at the 5% significant level. Except for ICT capital, there is a bidirectional Granger causality relationship between contribution of non-ICT, L, and TFP growth to value added growth in the short run. As a result, contrary to Gholami (2006) and Van Ark et al. (2003), at the aggregate level, ICT is the determinant factor for economic and TFP growth in Japan, but only in the long run.

Evidently, the ICT contribution effect was significantly positive, and quite considerable in the ICT-producing (2.277) relative to the ICT-using (-0.249) sectors. Moreover, regarding the differential impacts of ICT in the ICT-producing and ICT-using industries, the impact of ICT immediately turns into an insignificant level. We may possibly conclude that the worthwhile impacts of ICT largely focused on ICT intensive industries similar to Jorgenson et al. (2003) and Van Ark et al. (2003).

Furthermore, an insignificant ICT coefficient in the two-step System GMM results shows that adoption of new ICT was slow and smaller than the contribution of conventional inputs like non-ICT and labour. Japan needs to create a more conducive environment for technological diffusion. Some areas of inadequacy may exist in the Japanese ICT strategies to ensure a sustained period of economic growth that require attention (Gholami, Sang-Yong, & Heshmati, 2006). Updated reports of the Japanese economy suggest that investment in ICT could have had a negative effect on economic growth in the short run (Japan Economic Update, 2002). According to Figure 4-2, “Textiles, leather and footwear” industries in Japan have the highest proportion of value added growth by an average 17% growth rate per year attributed to the other sectors, even though these industries are neither ICT-producing nor ICT-using sectors. Therefore, the economic growth of Japan is affected by “Textiles, leather and footwear” as a main productive sector while ICT has an insignificant impact on this industry.

6.2.2 **Sweden**

In the early 1990s, the growth in productivity in the Swedish manufacturing industry was probably the largest within the EU countries. Although it is obvious that a declining trend in productivity growth was a global phenomenon throughout the 1990s, Sweden responded strongly. It is a well-known fact that sustainable enhancement in the supply of factors performs a significant role in enhancing total factor productivity. ICT with minimum standard deviation has the least fluctuation among the effective components of economic growth and its spillover effects through TFP contribution increased considerably (57 per cent).

With regards to the ICT influence on industrial output growth, we are able to classify that the estimated short run impact for the period 1990-2007 is positive and significant.

Particularly, its magnitude means that a 1 per cent rise in ICT capital leads to a 0.93 per cent improvement in output growth. We also noticed that the impact of non-ICT capital is significantly negative (-0.046). In contrast to the results for Japan, it seems that ICT as new modern capital has been replaced by non-ICT capital in Swedish industries because these results showed significant complementary effects between ICT and non-ICT capital.

With respect to the dynamic fixed effect estimator results of Sweden, most cases confirm the impact of ICT on total factor productivity as negative (-0.9801) and also significant at the 5 per cent significant level in the short run. This proof is in line with the theoretical foresight that the impacts of ICT are anticipated with a time lag at the industrial level, which is in line with the results for Japan. Furthermore, it is revealed that there is long run and short run bidirectional Granger causality among GDP growth and contribution of ICT, non-ICT, L, and TFP growth are at the 5 per cent and 10 per cent level, respectively. In addition, the findings indicated that there is panel short run and long run bidirectional causality among ICT, TFP growth, non-ICT and TFP at the 5 per cent and 10 per cent significant levels.

The long run results are consistent with Dimelis and Papaioannou's (2011) findings for a panel of EU and US countries, as developed countries, but differ with Vu's (2011) findings for a panel comprising of six countries of the Gulf Cooperation Council. The long run System GMM estimations give the impression that the TFP contributed positively and significantly (0.963 per cent) to output growth. From the PMG estimators finding, the overall ICT growth contribution is positive and significant. However, the System GMM results revealed that these positive effects stemmed more from ICT-using industries because the effects of ICT-producing industries are insignificant to value added growth.

6.2.3 **Australia**

Australia is a country with strong TFP growth in ICT-using industries but not important as an ICT-producing sector. For this reason, Australia recorded significant development in ICT investment in the 1990s and achieved a considerable growth between 1990 and 2007 (0.76 per cent). The growth decomposition analysis showed a 34 per cent contribution of ICT to the annual output growth in Australia. This is due to the quick diffusion of ICT among companies in the 1990s to match the rapid growth in investment. The explanation introduced in the literature, is, that in 1993-94, around 50 per cent of firms in a great number of sectors had computers and around 30 per cent had easy Internet access. By 2000-05, these percentages had grown to nearly 85 per cent and 70 per cent, respectively (Gretton et al., 2002).

The panel Granger causality results reported that a 1 per cent increase in ICT contribution increases GDP by 0.41 per cent, while a 1 per cent increase in L, non-ICT, and TFP increases the value added growth by 0.20 per cent, 0.19 per cent, and 0.19 per cent, respectively. It is important to note that non-ICT capital has become insignificant to GDP growth in the short run.

There is bidirectional long run causality among value added growth, contribution of ICT, non-ICT, L, and TFP pairwise. Therefore, we could identify ICT as a major source of growth in the Australian sectors over 1990-2007 (0. 41 per cent). In addition, ICT has a negative and significant relationship with TFP in the short run as well as in the long run. The findings indicated that there is unidirectional short run panel Granger causality running from EG, labour capital and TFP to non-ICT. This means that non-ICT in Australia might not be the determining factor of output and TFP growth in the short run. To sum up, all the results of causality evidence are in line with the Swedish industrial results.

The one-step GMM estimates reveal that earnings to ICT were considerably greater in the ICT-producing sectors than in the ICT-using sectors. This attestation remains in line with the works of O'Mahony (2005) and Van Ark (2010); hence, it could be claimed that there is a robust prospective to exploit growth profits in the Australia sectors that can make extensive use of ICT. The outputs of one-step and two-step GMM have demonstrated that absolutely no significant complementary impacts occur between ICT and non-ICT capital.

Table 6-1. Overall industrial level results, significant effects of ICT on EG and TFP

Country	Regional Rank in ICT	ICT & EG Short- run	ICT & EG Long- run	ICT & TFP	Return in ICT-prod & ICT-use
Sweden	1	(+) significant	(+) significant	(-) significant	ICT-P < ICT-U (+) <(-)
Australia	5	(+) significant	(+) significant	(-) significant	ICT-P > ICT-U (+) > (-)

Source: Author Analysis, 2013

The significant effects of ICT on growth of GDP and TFP in Table 6-1 shows Sweden and Australia recording a significant positive relationship not only in the short run but also in the long run.

6.2.4 **Finland**

Finland switched itself during the twentieth-century from a backward agrarian country reliant on the natural resources into an advanced industrial society whose telecommunications manufacturing is at the leading edge globally. The flagship of Finnish telecommunications is undoubtedly Nokia (Häikiö, 2007). The labour contribution to growth was negative (-23 per cent) and ICT contribution was still low (only 9 per cent), however, high growth in TFP (2.31 per cent) and EG (2.42 per cent) has been observed. Thus, Finland was not fast in employing information technology since it was implementing telecommunications technological innovation. However, presently it can be considered as one of the primary producers of information technology (Ojala, Eloranta, & Jalava, 2006).

We could not find evidence of short run causality running from ICT and non-ICT to value added growth and TFP, suggesting that GDP and TFP growth have not been influenced by the contribution of ICT and non-ICT growth. This does not have a significant impact on these variables in the short run while the long run effects are significant. This evidence is in a line with Gordon (2000); Jorgenson (2001); Jorgenson and Stiroh, (2000); Oliner and Siche (2002) who contended that technological progress in ICT stimulates the growth of total factor productivity in the sectors, and, hence, of aggregate TFP in the long run.

The results of the causality tests revealed long run bidirectional Granger causality running from real GDP growth to the contribution of L, ICT, non-ICT, and TFP growth at the 5% significant level. As a result, contrary to Gholami (2006) and Van Ark et al. (2003) at the aggregate level, ICT is the determinant factor for economic and TFP growth in Finland, but only in the long run. There is absolutely no causality relationship between GDP growth and non-ICT capital in the short run. Specifically, the produced estimates state that the ICT contribution was 0.37 per cent greater in ICT-producing and 0.33 per cent greater in ICT working with sectors (compared to the remaining sectors). This evidence is consistent with the findings of Jalava (2003), Jalava and Pohjola (2002, 2007) in that Finland was not as effective in implementing information technology since it is adapting telecommunications technology. Nokia's portion of the global mobile device shop was nearly 35 per cent. This is particularly topical in a country such as Finland that has enjoyed the advantages of the Nokia phenomenon. For instance, this is a profitable production of a new technology – however, there is still certainly room for enhancement in the usage of the new technology in the production procedures of other sectors. Furthermore, no significant complementary issues emerge between ICT and non-ICT capital.

To sum up, due to the insignificant effects of ICT on growth from the GMM estimators for Finnish industries, it is not sufficient to just promote industries that produce ICT equipment and goods. It is equally important that the rest of the economy, as an ICT consumer, takes on board the ICT-produced industries.

6.2.5 **Denmark**

Computer software is an essential investment (76 per cent) classification in ICT in Denmark (Aghion & Howitt, 1997). The ICT contribution is significantly higher than other factors (38 per cent) where the contribution of TFP to value added is only 9 per cent in Denmark. Predominantly, the Nordic countries (Denmark, Finland and Sweden) have related identical high shares for software, which suggests massive diffusion; however, as yet, this does not seem to have translated into substantial acceleration of the growth in productivity of these countries (Aghion & Howitt, 1997). In contrast to Finland, ICT-production industries in Denmark are relatively smaller compared to other EU countries.

With respect to the ICT impact on output growth, we can perceive that the estimated short run effect for the period 1990-2007 is insignificant and that the non-ICT, labour and TFP impacts are also insignificant in the short run. In contrast, all of these production factors have significant effects on output growth in the long run.

With respect to the causality results for Denmark, this has confirmed the impact of ICT on total factor productivity as negative (-1.213) and significant at the 5 per cent level. This evidence is consistent with the productivity paradox that the effects of ICT are expected with a time lag at the industrial level. However, the major source of TFP growth is annual output growth, which has a significant positive effect on TFP in the short run (0.886) and long run (0.130).

The results indicated that only long run bidirectional Granger causality is established among GDP growth and contribution of L, ICT, and non-ICT growth at the 5 per cent level, respectively. There is a unidirectional long run Granger causality running from TFP growth to the contribution of ICT, non-ICT, labour and GDP growth at the 5 per cent significant level whereas short run Granger causality ran from EG to TFP. Therefore, ICT investment growth cannot be a short run growth policy objective in Denmark but can be targeted as a long run policy. Danish industries are able to pay more attention to ICT spillover effects through TFP growth in the short run and dramatically increase industrial output growth by high TFP in the long run.

System GMM estimates show that the output elasticities of ICT (1.34 per cent) and non-ICT (1.99 per cent) capital recorded a positive relationship at the 5 per cent significant level. The general ICT growth contribution is positive and significant in both the one-step and two-steps results. These results are in line with long run PMG estimators implying that ICT should be able to play a major role in increasing growth in the Danish sectors by way of its quicker ICT capital accumulation. Furthermore, ICT was significantly higher in the ICT-producing industries than ICT-using sectors. This research is basically in agreement with the works of O'Mahony and Van Ark (2003), who argued that there is solid potential to exploit growth profits in the EU service sectors that make extensive use of ICT. However, no significant complementary effects exist between ICT and non-ICT capital.

Table 6-2. Overall industrial level results, insignificant effects of ICT on EG and TFP

Country	Regional Rank in ICT	ICT & EG Short- run	ICT & EG Long- run	ICT & TFP	Return in ICT-prod & ICT-use
Japan	4	(-) insignificant	(+) insignificant	(-) insignificant	ICT-P > ICT-U (+) > (-)
Finland	4	(-) insignificant	(+) significant	(+) insignificant	ICT-P > ICT-U (+) > (+)
Denmark	3	(+) insignificant	(+) significant	(-) significant	ICT-P > ICT-U (+) > (-)

Source: Author Analysis, 2013

We have summarised the results of the industrial level data findings in Table 6-2, which illustrates the insignificant effects of ICT on GDP growth.

6.3 Comparative Results between Asia-Pacific and EU Countries

As the telecommunications revolution has taken place in much of Asia-Pacific, it looks like it may have transformed this model. With open economic policies and export-oriented investment in technology, the countries of Southeast Asia have demonstrated that such a method produces trade surpluses, increasing returns and despite the current financial turbulence of the region, a long-term basis for economic growth can be attained (Jussawalla, 1999).

The drastic and large size of growth in the worldwide ICT market has permitted many countries to attain astounding success by proactive development of their ICT industry. The "East Asia Miracle" was a sign of success of the respective governments in Singapore, Taiwan, Korea, and Japan in pursuing the ICT-producing sector as a strategic industry while becoming large producers in the worldwide ICT industry (Hanna et al., 1996). ICT diffusion continues to be the core of competiveness and growth through Internet application and computerization of the East Asian economies, even though many East Asian countries have been very successful in the development of their ICT-producing sectors (Yusuf & Evenett, 2002).

Based on our results between Asia-Pacific and the EU aggregate level findings, the highest contribution of ICT was registered by Australia (0.650 Hanna) with a 3.246 Hanna annual GDP growth in the Asia-Pacific group while the top most contributor of ICT in the EU zone is Switzerland with (1.435 per cent) and 3.283 per cent annual growth rate. The annual average TFP and GDP growth for Asia-Pacific were 0.861 per cent and, 3.843 per cent, respectively, over the period 1990-2011, which were greater than the EU economies with TFP at 0.559 per cent and 2.538 per cent growth rate. However, the average contribution of ICT growth for Asia-Pacific was 0.482 per cent during the period, which is smaller than the average EU economies of 0.844 per cent growth rate. Therefore, it seems that the higher growth rate of GDP in Asia-Pacific than for the EU countries might be attributable to the ICT contribution. This explains the lower average ICT contribution in Asia-Pacific countries, which is similar to Vu (2013), who indicated that the successful growth of Asia relies heavily on investment, technology catch-up and openness to trade.

Indeed, there are some differences between the Asia-Pacific and the EU when it comes to ICT and TFP contributions to GDP growth, which could be brought under the hypothesis of lagging ICT diffusion. This proof implies that ICT developed is not the only factor presenting differences in productivity and GDP growth between European and Asia-Pacific countries but that ICT penetration may also have a major role.

Therefore, from the findings it was apparent that ICT contribution to value added across two regional groups of countries is not strongly correlated with the level of income and TFP. Consequently, the impacts of the other effective factors of GDP growth should be controlled by employing more related factors in the model like education, innovation and trade. A critical feature of the debate over the existence of ICT spillover is whether the ICT capital stock can also boost economic growth through positive spillover effects on TFP, if ICT capital is like knowledge capital. Thus, based on the endogenous growth model, new added variables that are related to the spillover effects of ICT have increased the significance of the model at the aggregate level.

From the causality study, in the short run, in both regions, there is a unidirectional relationship causality running from economic growth to ICT contribution. In contrast to the results of Hwan-Joo et al. (2009) for 29 countries, non-ICT contribution has a causal relationship with economic growth and plays a key role in increasing growth. ICT contribution does not have a strong interdependent relationship with economic growth across Asia-Pacific and EU countries between 1990 and 2011. This result is inconsistent with recent research, which draws attention to the serious weakness of the EU ICT sector: the lowest efficiency levels are shown by those ICT activities in which most new value creation is taking place.

The main reason is that the operation in ICT and related services is not fully exploiting the advantages offered by their network of contacts. This constitutes a major drawback that constrains the ability of European countries to capitalize on the innovation and growth-enhancing effects of these activities throughout the economy (García-Muñiz & Vicente, 2014).

System GMM employs additional instruments compared to the difference GMM, and it may well not be suitable to apply the System GMM dataset with a small number of countries. Therefore, we are going to use first-difference GMM for the aggregate level part due to the small number of countries (N= 6 T= 11) and System GMM for the industrial level part with large cross-sectional data (N=21, T=17).

TFP growth shows significant and positive effects on GDP growth for both regions during the two periods with a difference in magnitude, inasmuch as the positive effects for the Asia-Pacific countries in the second period is higher than for the first period. However, for the EU, the growth of TFP in the first period is more effective than GDP growth. Overall, the return on TFP growth in the EU is higher than for the Asia-Pacific countries.

The ICT growth effect only seems to have risen significantly in magnitude during the 1990s and 2000s for the EU countries. While in the Asia-Pacific countries, both the magnitude and significant effect on GDP growth of ICT during the 2000s declined. This can be interpreted as ICT being the engine of growth in the 1990s in the Asia-Pacific countries, whereas it had the same role for the EU economies in the 2000s. This is similar to the results of previous studies that mentioned that the multiplier effect of the ICT sectors on the rest of the economy had declined significantly during the period 2000-2005 compared to 1995-2000 (Rohman, 2013). Rohman (2013) applied different methods like Input-Output (IO) methodology to investigate the contribution of the ICT sectors to economic performance in the European economies but obtained similar results to ours.

According to the Asia-Pacific results, between 1990 and 2000, the ICT effect increased considerably, representing an incredibly positive and significant correlation with output growth. This attestation highlights the stylised facts displayed in the literature that the ICT growth contribution enhanced noticeably after 1995, especially in Asia and the US economies but not in the EU countries. However, for the EU countries, the relative importance of ICT rose significantly during the second period, from -0.94 to 1.22, whereas for Asia-Pacific it dropped from 5.214 to -5.915.

These final results confirm that ICT can begin to play a major role in reinforcing growth among the EU countries, via its faster capital accumulation. Generally, it appears that when evaluating the results of a couple of group countries, the ICT effect is higher in the EU economy than for the Asia-Pacific countries not only from the direct effects of ICT as a capital but also through TFP growth and additional variables by the positive spillover effect.

In the prior investigations on a country with a small ICT-producing sector or without, should not experience the growth impulses of using ICT capital input. Currently, doubt concerning the role of the ICT-producing industry has been voiced, specifically from the viewpoint of reviewing certain EU economies with Asia-Pacific countries. The current research reveals that for the period under review, the shortage of a large ICT-producing sector is neither a necessary nor a sufficient condition for countries to enjoy the growth impacts of ICT. This is exhibited in the case of Australia. While having a minimal ICT-producing industry, it has clearly reaped the benefit from ICT capital services.

Generally, there is no discernible systematic relationship between the size of the ICT-producing industry and the ICT contribution to output growth. This certainly does not signify that ICT-producing sectors have not contributed to current growth patterns. This appears from the analyses of the sectoral causes of macro-economic TFP growth (Colecchia & Schreyer, 2002). For Sweden and Finland, a major section of the overall TFP growth may be traced back to the ICT-producing sectors (computers, semiconductors, and communications equipment). Technological improvements also represent lower equipment prices as well as capital deepening in other sectors; however, this impact is not linked to the presence of an ICT-producing industry.

From the results reported for five countries, the returns to ICT were higher in ICT-producing than ICT-using industries, while it seems that ICT-using industries only have a significantly negative effect on growth in Japanese and Swedish industries. We conclude that the useful impact of ICT is mainly centred on the ICT intensive sectors. When the number of ICT-using industries is going to be large in each country, the significance of ICT capital on value added would also be large, as shown by the results from Australia and Sweden. These findings are also confirmed by the panel data analysis of Vu (2011) on a multi-country dataset concerning ICT penetration. Similar to our study, he found a robust result with a causal link between ICT and growth by employing GMM estimators.

Regardless of the truth that the growth importance of ICT decreased inappreciably through the second sub-period in Asia-Pacific countries, basically, it is not often used in ICT growth potential compared to the EU. Consequently, there may be a need for the Asia-Pacific to provide an environment that is more effective to technology diffusion. Essentially, the presence of highly skilled labour is of fundamental importance to maximise the profits from ICT. Despite the fact that the new experience of the EU economic growth is disappointing compared to the Asia-Pacific countries, the ICT effect in the Asia-Pacific region was stronger than for the EU.

To sum up the industrial level analysis, according to our results, Sweden's industries, as the globally second ranked ICT development indexed country, benefited from ICT-using more than ICT-producing. Therefore, Swedish industries captured a significant and positive contribution of ICT either on value added growth or total factor productivity growth. This is similar to the recent study by Hall, Lotti, & Mairesse (2013) who mentioned that ICT investment is more important for productivity than other factors in the EU industries. They also explored the possible complementarity between R&D and ICT in innovation and production. However, concerning the growth of Japanese industries, the ICT contribution has not only been considered as an effective factor on value added and TFP growth but it has a negative impact on TFP growth. This is associated with the insignificant effects of ICT-using industries in which Japan is ranked 13th globally according to the ICT development index.

Even with the requisite institutional and human capital capabilities, it is not sufficient to just promote industries that produce ICT equipment and goods. It is equally important that the rest of the economy, as an ICT consumer, takes on board the ICT-produced. These results have implications for the discourse on economic development in general.

Therefore, we can interpret that the rank of the ICT development, ICT-using, and ICT-producing status of a country could influence the usefulness of ICT contribution on the country's economic growth.

Bi-directional causality between the value added growth and ICT contribution was only observed in Sweden and Australia, which are ranked 2nd and 14th on the global ICT development index, respectively. In Japan, Finland and Denmark, which are globally ranked as the 13th, 5th and 4th countries, respectively, according to the ICT development index, there are uni-directional relationships running from value added growth to ICT contribution growth. Therefore, it seems there is no relationship between the ICT rank status of countries and the significant effects of ICT on economic growth in these countries.

These countries first experienced economic growth then increased ICT contribution. The common point among all of the considered countries is that economic growth and TFP growth of the countries have been sourced from increasing ICT contribution. We can conclude that the pervasive use of ICT in countries or the presence of more ICT-using industries could be a sign of the dynamic and growing economy of countries. This kind of relationship has been observed more in the Asia-Pacific countries than in the EU countries at the aggregate level.

Regarding the spillover effects of ICT through TFP growth, ICT has significant effects on TFP growth in Sweden, Australia, Denmark and the EU group of countries. ICT only has a positive and significant effect on TFP growth for Swedish industries, which has the highest ranked ICT development index among all the countries covered. On this point, the average total ranking of Asia-Pacific countries for the ICT development index is 10.83 whereas for the EU countries it is 4.83. Therefore, ICT is only an effective factor for TFP in the EU group of countries with higher ICT development ranking.

Thus, in agreement with our research hypothesis number 6, we can conclude that ICT has a higher positive spillover effect on value added growth through TFP in those countries that are ICT developed as compared to those which are ICT less developed according to the ICT development index.

Table 6-3. Overall Aggregate level results, insignificant effects of ICT on EG and TFP

Country	Average Rank in ICT	ICT & EG Short –run	ICT & EG Long- run	ICT & TFP	ICT & non-ICT
Asia-Pacific	10.88	(+) insignificant	(+) significant	(-) insignificant	ICT > non-ICT (+) > (+)
EU	4.83	(+) insignificant	(+) significant	(-) significant	ICT < non-ICT (+) < (+)

Source: Author Analysis, 2013

It is important to note that in the aggregate level analysis, as shown in Table 6-3, ICT registered a negative and significant effect on TFP growth for the EU countries. This can be interpreted as the productivity paradox still exists in the EU countries and that the ICT spillover effects are accompanied by the time lag in the EU countries. However, there is no causal relationship between ICT and TFP growth among the Asia-Pacific countries despite the support of a short run and long run cointegration relationship based on Mehrara and Falahati (2013) for Middle East Asian countries during the period 1990-2010.

Independently from TFP education, openness and high quality patents are supposed to be among the main determining factors of the difference in ICT spillover impact on output growth across economies. Along with these elements, it is predicted that innovation and technology trade is usually an essential determinant for the ICT spillover impact on growth due to the fact that the countries with a higher level of trade and innovation may gain large benefits from the ICT, for which online trade is the foremost way of export and import (Vu, 2005). The significance of the education and patent variables suggest that educational and patent attainments are an important determinant of the ICT contribution to growth. The coefficient is negative but higher in the EU than for Asia-Pacific, which suggests that the impact of education and patent application were somewhat accelerated and more effective in the EU economies. The outcomes indicate that the openness provides some negative effect on ICT contribution to output growth. However, this effect is not statistically significant.

The global picture of the effect of ICT on output growth is a mixture of static and dynamic features. The results of GMM demonstrate that the size of the ICT effect on output growth for EU economies in the second period highly predicted compared to the first period but for Asia-Pacific countries the first period highly predicted compared to the second period.

6.4 Policy Implications and Further Studies

The characteristics of General-purpose Technologies (GPT) imply that a crucial role can be played by the governments in the enhancement of ICT's impact on the economic development in countries. Regarding ICT for policy agendas, governments, especially in developing countries, have a tendency to focus their resources on two endeavours:

1. Pursuing the ICT-producing sector as a "strategic" industry to improve its growth and formation.
2. Fostering the ICT diffusion through to all economic sectors.

The results of this research have proven the high opportunity cost of only pursuing the ICT-producing sector as a key industry and disregarding efforts to foster ICT diffusion throughout the economy in countries such as Japan and Finland. Thus, it is vital for governments to deliberate on the opportunity cost of overlooking ICT diffusion when spending a substantial amount of their scarce resources in funding the ICT-producing sector. Therefore, with the underlying concerns, the government's ICT agenda is to get access to ICT for all sectors of the economy.

Furthermore, the pivotal role of complementary investments of ICT should be considered in the process of growth. When an innovative and efficient GPT arrives, resources are pulled out of the production of final goods and pushed into the research and development sector for the development of new complementary investments. At this initial stage, the economy suffers TFP and GDP growth losses. Therefore, in this stage negative effects of ICT on growth can be observed in countries such as Japan and Finland.

The ICT's contribution to GDP growth in the Asia-Pacific is also lower than that of the EU, principally due to Asia's inferior share of production in ICT. In the longer run, the impact of ICT on growth will have to come primarily from its productive use in the services sector. This study shows the difference in the performance of the EU and Asia-Pacific countries and also the different industries. For instance, Australia and Denmark recorded a strong growth of ICT capital and a large contribution from ICT service flows to GDP growth. Comparatively, Japan and Finland, being the major producers of ICT, demonstrated the lowest contributions to GDP growth.

As a result, countries, such as Japan and Finland, need to create a more encouraging environment for technological diffusion and increase the number of ICT-using industries. The existence of highly skilled labour is mostly needed to maximize ICT derived benefits. More policies should be directed to product market competition or to reduce the regulation of the ICT market (Gust & Marquez, 2004), so as to increase the incentives for technological investment.

Our results have implications for the discourse on economic development in general. First, the prevailing arguments in favour of technological capacity enabled growth have not taken into account the short-term costs that include reduced economic growth. Such a strategy has also been silent on the distributional consequences of this growth strategy. Second, even with the requisite institutional and human capital capabilities, it is not sufficient to just promote industries that produce ICT equipment and goods. This is due to ICT capital deepening and TFP growth from ICT-goods production, investment in ICT capital may also enhance TFP growth. This occurs while ICT use causes spillover impacts and encourages disembodied technical progress. It is equally important that the rest of the economy, as an ICT consumer, takes on board the ICT-produced. In both these areas, the state has an important role to play.

Third, digitally stored information (R&D, financing, insurance services, accounting, payroll, etc.) can already be generated away from the office. The intelligent use of information is a source of increased productivity, just as natural resources were in the twentieth-century. The difference is that natural resources are tied to a certain place, whereas information has no such restrictions. Geography is no longer of the essence, as everyone has equal access to global information networks. The new restructuring of the economy may be as great as the one witnessed over 100 years ago when electricity and the telephone were invented.

Based on the above analyses, it is recommended that a structure for formulating an efficient government ICT schedule should be in place to foster ICT utilisation and diffusion across the economy.

The framework contains four main factors – Concepts, Competency, Costs and Benefits – for both Asian and European countries. A powerful government ICT agenda has to smartly enhance each of the four components and the interplay among them.

6.4.1 **For Asian countries, the suggestions for policy implications**

Asian people are less familiar than EU people with the concept and competency of ICT; therefore, the following may be recommended for Asian countries:

1*) Concepts*

The "Concepts" component concerns the fundamental knowledge of how a country can gain benefits of ICT revolution in terms of economic growth and development. Therefore, future research proposals could follow the following components:

- Impact of ICT on economic growth and development, and the potential applications of ICT should be understood profoundly by the policymakers. Furthermore, they should be mindful of the risks involved due to the lack of strategic planning in providing the ICT sector with a substantial amount from its limited resources.
- Key determinants of ICT diffusion should be comprehended by the policymakers, which include the educational level, institutional quality and the openness of the economy of the population. Effective measures for promoting these determinants assure a fundamental enhancement in the country's capability to reap the benefits of the ICT spillover effects. Policymakers should be very cautious when considering market-distorting policies in their ambition to promote ICT diffusion. Once policymakers have adopted the right concepts, the government ICT agenda has a solid foundation for a successful implementation.

2) *Competency*

Human capital or the competency of a population, particularly the labour factor, is the vital element in a nation's capacity to absorb the penetration of ICT. Thus, we suggest the following in promoting the "competency" component to enhance the fast diffusion of ICT:

- Introduction of policies and mechanisms that aid the education sector should be the main focus of investment from both non-government and government sectors. Additionally, the government should play a proactive role in reforming the education sector with major investments to make it a key engine driving the economy towards a knowledge-based economy. Moreover, English fluency should be promoted for Asian countries by the government in applying and endorsing the use of the language in a variety of training and educational programmes.

- Generous and extensive support for ICT-related training should be provided by encouraging people to augment ICT skills and their understanding of ICT applications. Moreover, continuous learning should be consistently supported because new technologies and ICT continue to evolve at a fast pace.
- Promoting the quality and commonness of access to ICT services, mainly the Internet. In particular, governments should be proactive in providing financial incentives, professional guidance and training for Internet cafes/E-centres, especially in remote areas.
- Encouraging institutional competition increases the depth of ICT diffusion and controls their development over time.

6.4.2 **For European countries, the suggestions for policy implications**

With a large consensus that growth in the Asia-Pacific countries has benefited not only from the production of ICT but also from its adoption of ICT-using industries faster than the EU, more evidence becomes available that EU countries have taken longer time to enhance the ICT-using industries. Most European economies show considerably lower investment levels in ICT goods and software than the Asian countries. Furthermore, as productivity growth in the Asian countries has accelerated, European productivity growth has slowed down since the mid-1990s. Therefore, it has been suggested that EU countries should give more consideration to the cost and benefit implications of ICT structures in the country:

3) *Costs*

Cost is a key factor underlying the differences in ICT diffusion. Even for EU countries, the direct costs of telecommunication services and ICT equipment have also significantly affected their ICT diffusion, as pointed out by Ramirez (2007). The policies addressing the "Costs" component include the following:

- Introducing domestic ICT market and nurturing competition between ICT equipment vendors.
- Relaxing the telecommunication sector through profound and extensive regulatory reforms intended to lower the costs and improve the service quality.
- Encouraging the vibrancy and growth of ICT-related services, which helps households and firms minimise the cost of investment in ICT.
- Presently, telecommunication carriers grant subsidies to encourage the selling of ICT equipment such as mobile phones; therefore, users are frequently able to purchase comparatively cheaper units that provide a high degree of functionality. This structure is certified as having a great impact on the highly functional terminals to broadly enhance the competitiveness of portable devices in the market. Nonetheless, to provide more competitively priced products, the debate on substituting the current scheme of funding with a new price plan should be ongoing.

4) *Benefits*

While there might be limitations in decreasing the costs of obtaining and using ICT, the potential for increasing the benefits of investment in ICT is huge. Hence, increasing the benefit of investment in ICT should be the main emphasis for the government in the execution due to the increasing contribution of ICT on GDP growth. The benefit of investment in ICT can be improved in the following ways:

- Consistently enhancing the whole business climate by encouraging the openness of the economy and its assimilation into the worldwide market, nurturing competition among firms, improving the effectiveness and transparency of the regulatory framework, and upgrading the quality of governance.

- Providing incentives and creating solid foundations for the development of e-commerce.
- Making wide-ranging investments on e-government, which permits the citizens to gain considerable benefits when dealing with the government online.
- Encouraging Internet-enabled services, particularly those that deliver information and consulting services that are critical for firms to improve their global competitiveness and integration.
- Encouraging networking and also collaboration; specifically, establishing Cluster Initiatives (CIs) that strengthen bonding and cooperation among firms, business associations with Asian countries. Thus, Asia would be a lucrative market for European producers. Providing incentives for complementary investments allows firms to reap higher benefits from investing in ICT. Telecommunication infrastructure significantly affects both the costs and benefits of investment in ICT, and, therefore, the diffusion of ICT. For example, Internet applications can be more prolific, and the Internet user can reap more benefits from the Internet at a lower cost (for less time) if the country is equipped with a high bandwidth capacity, which determines the quality and speed of Internet access.
- Restructuring the prevailing regulatory framework related to telecommunication infrastructure development and operation to make it more appropriate for fast changes prompted by the ICT revolution and globalisation (Vu, 2009).
- Advancement of the region's telecommunications industries is going to be determined by factors, such as the economies of scale versus diseconomies because the former plays a more determining role in cost reduction than scale economies.

The lesson learnt is that the output and productivity impacts of the new technologies can be long-delayed. Consequently, current policymakers should consider from whence the next wave of productivity growth will come. As shown, ICT has already contributed to economic growth by improving productivity in the industries producing ICT equipment. It has also enhanced capital deepening, i.e. through the substitution of ICT capital for other forms of capital such as non-ICT. However, the effects on TFP from the re-organization of production and work are yet to come. The ongoing digitalization and outsourcing of business processes will result in the restructuring of white-collar work at the global level, and, consequently, may bring about a new wave of productivity growth.

In conclusion, although this study has added value to previous works via its wider coverage sectors in the search for ICT contribution to output and productivity growth in ICT developed countries of the two regions, there are, however, areas for further research in ICT contribution. For instance, there is a solid requirement for a better and longer series of ICT, non-ICT, labour, and TFP contribution data for individual countries in different industries.

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APPENDIX A-Panel Unit Root Tests, All Individual Countries

Methods	Breitung (2000) Level, First difference	Hadri(2000) Level, First difference	Pesaran (2003) Level, First difference	Maddala &Wu(1999) Level, First difference	Levin-Lin-Chu(2002) Level, First difference
Japan					
EG	0.076(0.530) -2.262*(0.012)	3.105*(0.001) 0.112(0.455)	2.628 [a](0.996) -3.530[a]*(0.000)	-0.068(0.4730) -6.243*(0.000)	0.897(0.815) -18.766*(0.000)
L	0.076(0.530) -2.262*(0.012)	3.105*(0.001) 0.112(0.455)	2.628 [a](0.996) -3.530[a]*(0.000)	-0.068(0.4730) -6.243*(0.000)	0.897(0.815) -18.766*(0.000)
ICT	0.076(0.530) -2.262*(0.012)	3.105*(0.001) 0.112(0.455)	2.628 [a](0.996) -3.530[a]*(0.000)	-0.068(0.4730) -6.243*(0.000)	0.897(0.815) -18.766*(0.000)
Non-ICT	0.076(0.530) -2.262*(0.012)	3.105*(0.001) 0.112(0.455)	2.628 [a](0.996) -3.530[a]*(0.000)	-0.068(0.4730) -6.243*(0.000)	0.897(0.815) -18.766*(0.000)
TFP	0.076(0.530) -2.262*(0.012)	3.105*(0.001) 0.112(0.455)	2.628 [a](0.996) -3.530[a]*(0.000)	-0.068(0.4730) -6.243*(0.000)	0.897(0.815) -18.766*(0.000)
Finland					
EG	-1.549**(0.061) -3.803*(0.000)	2.682*(0.004) -0.945 (0.828)	-0.357a(0.361) -4.474a*(0.000)	2.743*(0.003) 12.286*(0.000)	2.359(0.991) -8.624*(0.000)
L	-1.549**(0.061) -3.803*(0.000)	2.682*(0.004) -0.945 (0.828)	-0.357a(0.361) -4.474a*(0.000)	2.743*(0.003) 12.286*(0.000)	2.359(0.991) -8.624*(0.000)
ICT	-1.549**(0.061) -3.803*(0.000)	2.682*(0.004) -0.945 (0.828)	-0.357a(0.361) -4.474a*(0.000)	2.743*(0.003) 12.286*(0.000)	2.359(0.991) -8.624*(0.000)
Non-ICT	-1.549**(0.061) -3.803*(0.000)	2.682*(0.004) -0.945 (0.828)	-0.357a(0.361) -4.474a*(0.000)	2.743*(0.003) 12.286*(0.000)	2.359(0.991) -8.624*(0.000)
TFP	-1.549**(0.061) -3.803*(0.000)	2.682*(0.004) -0.945 (0.828)	-0.357a(0.361) -4.474a*(0.000)	2.743*(0.003) 12.286*(0.000)	2.359(0.991) -8.624*(0.000)
Denmark					
EG	0.268(0.606) -9.992*(0.000)	3.964*(0.000) 0.668(0.252)	0.318(0.625) -5.123a*(0.000)	-0.125(0.549) 1.911*(0.028)	-1.265(0.103) -4.209*(0.000)
L	0.268(0.606) -9.992*(0.000)	3.964*(0.000) 0.668(0.252)	0.318(0.625) -5.123a*(0.000)	-0.125(0.549) 1.911*(0.028)	-1.265(0.103) -4.209*(0.000)
ICT	0.268(0.606) -9.992*(0.000)	3.964*(0.000) 0.668(0.252)	0.318(0.625) -5.123a*(0.000)	-0.125(0.549) 1.911*(0.028)	-1.265(0.103) -4.209*(0.000)
Non-ICT	0.268(0.606) -9.992*(0.000)	3.964*(0.000) 0.668(0.252)	0.318(0.625) -5.123a*(0.000)	-0.125(0.549) 1.911*(0.028)	-1.265(0.103) -4.209*(0.000)
TFP	0.268(0.606) -9.992*(0.000)	3.964*(0.000) 0.668(0.252)	0.318(0.625) -5.123a*(0.000)	-0.125(0.549) 1.911*(0.028)	-1.265(0.103) -4.209*(0.000)
Sweden					
EG	-1.331**(0.091) -2.472* (0.007)	3.314*(0.001) 1.249 (0.106)	-0.038 (0.485) -1.771*(0.038)	1.848*(0.032) 7.164*(0.000)	12.4266 (1.000) -9.162* (0.000)
L	-1.331**(0.091) -2.472* (0.007)	3.314*(0.001) 1.249 (0.106)	-0.038 (0.485) -1.771*(0.038)	1.848*(0.032) 7.164*(0.000)	12.4266 (1.000) -9.162* (0.000)
ICT	-1.331**(0.091) -2.472* (0.007)	3.314*(0.001) 1.249 (0.106)	-0.038 (0.485) -1.771*(0.038)	1.848*(0.032) 7.164*(0.000)	12.4266 (1.000) -9.162* (0.000)
Non-ICT	-1.331**(0.091) -2.472* (0.007)	3.314*(0.001) 1.249 (0.106)	-0.038 (0.485) -1.771*(0.038)	1.848*(0.032) 7.164*(0.000)	12.4266 (1.000) -9.162* (0.000)
TFP	-1.331**(0.091) -2.472* (0.007)	3.314*(0.001) 1.249 (0.106)	-0.038 (0.485) -1.771*(0.038)	1.848*(0.032) 7.164*(0.000)	12.4266 (1.000) -9.162* (0.000)
Australia					
EG	-0.697(0.243) 2.068*(0.019)	2.117*(0.017) -0.483(0.685)	1.186a(0.882) -1.815 a**(0.035)	-1.360(0.913) 5.153*(0.000)	-1.002(0.158) -4.479*(0.000)
L	-0.697(0.243) 2.068*(0.019)	2.117*(0.017) -0.483(0.685)	1.186a(0.882) -1.815 a**(0.035)	-1.360(0.913) 5.153*(0.000)	-1.002(0.158) -4.479*(0.000)
ICT	-0.697(0.243) 2.068*(0.019)	2.117*(0.017) -0.483(0.685)	1.186a(0.882) -1.815 a**(0.035)	-1.360(0.913) 5.153*(0.000)	-1.002(0.158) -4.479*(0.000)
Non-ICT	-0.697(0.243) 2.068*(0.019)	2.117*(0.017) -0.483(0.685)	1.186a(0.882) -1.815 a**(0.035)	-1.360(0.913) 5.153*(0.000)	-1.002(0.158) -4.479*(0.000)
TFP	-0.697(0.243) 2.068*(0.019)	2.117*(0.017) -0.483(0.685)	1.186a(0.882) -1.815 a**(0.035)	-1.360(0.913) 5.153*(0.000)	-1.002(0.158) -4.479*(0.000)

Source: Author Analysis, 2013

APPENDIX B-Panel Co-integration Tests, All Individual Countries

Methods	**Japan**	**Finland**	**Denmark**	**Sweden**	**Australia**
Kao test(ADF)					
Lag	3	3	3	2	3
t-statistic	-11.785*	-12.459*	-3.571*	-8.909*	-8.909*
Probability	0.0000	0.0000	0.0002	0.0000	0.0000
Pedroni (2004) test	Prob.	Prob.	Prob.	Prob.	Prob.
Panel v-Statistic	0.0013	0.0002	0.0472	0.0599	0.0014
Panel rho-Statistic	0.5081	0.1516	0.5674	0.5481	0.0070
Panel PP-Statistic	0.0000	0.0000	0.0088	0.0000	0.0000
Panel ADF-tatistic	0.0000	0.0000	0.0036	0.0000	0.0000
Group rho-Statistic	0.8478	0.6441	0.8565	0.9769	0.4920
Group PP-Statistic	0.0000	0.0000	0.0000	0.0000	0.0000
Group ADF-tatistic	0.0000	0.0000	0.0000	0.0000	0.0000

Source: Author Analysis, 2013