THESIS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

On the weightless economy:

Evaluating ICT sectors in the European, Asian and African regions

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Göteborg, Sweden 2012

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ISBN 978 – 91 – 7385 – 704 – 8

Doktorsavhandlingar vid Chalmers tekniska högskola
Ny serie Nr 3385
ISSN 0346 –718X

Division of Technology and Society
Department of Technology Management and Economics
Chalmers University of Technology
SE-41296 Göteborg, Sweden

Printed by Chalmers Reproservice
Göteborg, 2012

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Abstract

One of the most distinctive characteristics of the weightless economy is the increasingly important role of the Information and Communication Technology (ICT) sectors, which, according to the OECD (2009), consist of ICT products and media and content products. The ICT sectors have been identified as contributing significantly to the economy through production, measured by the value of the ICT outputs produced and the spillover effects to the other sectors, and the diffusion due to the higher penetration rate of ICT products and services and the impact of the end-users. This dissertation aims to investigate the problems underlying the production and diffusion sides of the ICT sectors based on specific characteristics in the European, Asian and African regions.

On the production side, the dissertation found that the low contribution by the ICT sectors to the output of the European economy during the later period of observation (2000-2005 compared with 1995-2000) is due to the sectors' high dependence on export effects and technological change effects, which have both declined. In Asia, a case study in Indonesia showed that the lower impact of the ICT sectors on the economy can be addressed from the dominant size of the domestic final demand affecting the change in output. Thus, the country is unable to upgrade the ICT sectors, as the general purpose technology (GPT) is supposed to allow greater linkage to be generated to the other sectors.

On the diffusion side, the dissertation found no evidence that any of the ICT devices have a long-term relationship with the socio-economic variables in Asia, particularly primary education and health. As in Asia, access to ICT devices (cellular and the Internet) has had very little impact on closing the income gap or on other quality of life (QOL) indicators, namely participation and productivity, in the African region.

On responding to these problems, the study found that a continual price decrease in the ICT sectors will lead to higher GDP growth as well as an increase in the inter-relatedness between ICT and the rest of the economy, solving the problem of disconnection in the European region. Moreover, the upgrading of broadband deployment that corresponds to increasing the speed level is also believed to enable greater opportunity for the European region to move forward in terms of economic progress. In Asia and Africa, there is an urgent agenda to build a stronger linkage between the rapidly growing ICT sectors and the socio-economic variables in the future as many studies have found that there is no linkage between production and diffusion in the region. Infrastructure provision is the most important issue in this regard.

Keywords: weightless economy, production, diffusion, economic growth, ICT sectors, broadband, cellular, Europe, Asia, Africa, input-output, probit, panel data, panel cointegration, Gini coefficient

List of appended papers

Paper 1 Rohman, I. K., & Bohlin, E. (2009). Is the European broadband public spending a sensible project? The opportunity cost concept and implications of the input-output analysis. *Paper prepared for the 37th Research Conference on Communication, Information and Internet Policy (TPRC).*

To be published: Rohman, I.K., & Bohlin, E. (2012). Is the European broadband public spending a sensible project? The opportunity cost concept and implications of the input-output analysis. In R. Taylor, &A. Schejter (Eds.), *Developing data-based information policy strategies.* State College: Penn-State University Press.

Paper 2 Rohman, I. K. (2012). The globalization and stagnation of the ICT sectors in European countries: An input-output analysis. Forthcoming. *Journal of Telecommunication Policy.*

Paper 3 Rohman, I. K. (2011). How important is the media and content sector in the European economy? *Proceedings of the 26th European Communication Policy Research Conference (EuroCPR).*

The revised version was submitted to: In J. Alleman, A. NíShúilleabháin, & P. Rappoport (Eds.), *The Economics of Information, Communication and Entertainment: The Impacts of Digital Technology in the 21st Century: A Festschrift in Honor of Lester D. Taylor.* Springer Verlag.

Paper 4 Rohman, I. K., & Bohlin, E. (2012). Does broadband speed really matter for driving economic growth? A case of OECD countries. Submitted to *International Journal of Management and Network Economics.*

Paper 5 Rohman, I. K., & Bohlin, E. (2009). Competition in the Swedish cellular industry: Nobody cares about older people. *Proceedings of the 2009 Eighth International Conference on Mobile Business* (pp. 30-34).

Paper 6 Rohman, I. K., & Bohlin, E. (2010). PANS in the Swedish cellular industry: How bright will it be? *Proceedings of 2010 9th International Conference on Mobile Business and 2010 9th Global Mobility Roundtable* (pp. 440-447).

Paper 7 Rohman, I. K., & Bohlin, E. (2012). Decomposition analysis of the telecommunications sector in Indonesia: What does the cellular era shed some light on?. *Proceedings of Regional International Telecommunication Society India Conference*: Telecom Policy, Regulation, and Management as Drivers for Transforming Emerging Economies.

Paper 8 Rohman, I. K., & Bohlin, E. (2011). An assessment of mobile broadband access in Indonesia: A demand or supply problem? *Internetworking Indonesia Journal*, *3*(2), 15-22.

Paper 9 Rohman, I. K. (2011). Relationship between ICT penetration rate and socio-economic variables in the Asian countries: A dynamic panel data approach. *Information Technology in Developing Countries*, *21*(3), 9-15.

Paper 10 Rohman, I. K. (2012). Will telecommunications development improve the quality of life in African countries? *Info*, *14*(4).

Paper 11 Rohman, I. K. (2010). The economic impact of IPTV deployment in the European countries: An input-output approach. *Proceedings of UBICOMM 2010, the Fourth International Conference on Mobile Ubiquitous Computing Systems, Services and Technologies* (pp. 486-494).

Acknowledgements

I always believe that when a particular time is priceless, it flies much too fast, hence, at some points, I really want to stop it for a while to enjoy every moment. My time as a PhD student at Chalmers University of Technology has undoubtedly been one of these times. The last four years have been the most fabulous time for which 'strong monotonicity' holds: I would like to have more chances to feel the spirit and the ambiance as a PhD student here. The PhD education has really allowed me to have the whole experience from all perspectives: courses, conferences, workshops and internships, as important building blocks to reshape me as a student, not only with the PhD as the ultimate goal but also as a stronger character for a future career. I am fortunate to be among the student here for whom the four years are so memorable, and two pages of acknowledgement will leave many important people unmentioned.

First and foremost, I would like to thank Professor Erik Bohlin who has guided and supervised me during the last four years. It is difficult to express how indebted I am to his kindness in and out of education activities. Besides guidance to the end of the PhD dissertation, Erik Bohlin has given me ample opportunities to contribute to research, projects and teaching, and to open the networks where the sources of data can easily be obtained. Erik Bohlin has always given me and the other international students the benefit of his patient reading and commenting on manuscripts with important suggestions as well as advice on the best way to investigate research problems.

I am indebted to my assistant supervisor Associate Professor Ann-Sofie Axelsson for her many valuable inputs and suggestions when I was finishing my dissertation. I thank Professor Gary Madden of Curtin University for his many critical inputs to my manuscript. It has also been a pleasure to have Professor Martin Cave of the Imperial College Business School as a discussant during the licentiate and the final seminars and he also gave me many important considerations for my study.

The study process could not have been conducted without the financial support provided by the Ministry of Communication and Information, the Government of Indonesia. I thank Bapak Dr Aizirman Djusan, Head of Research and Development at the ministry as well as Ibu Trini Tamara Riva and Ibu Eyla Alivia for the whole process of making everything easier from a funding perspective. I also thank the Institute for Economic and Social Research (LPEM FEUI), especially Dr Widyono Soetjipto, for continuous supports during this study. Dr Yogi Vidyattama (the Australian National University) and Dr Teguh Dartanto (Nagoya University) have also given me many valuable inputs concerning my research.

I did not expect that the sources of data would be easy to collect. I thank Post- och Telestyrelsen (PTS), Stockholm, the Ericsson Consumer Lab (especially Mr Vishnu Singh at the Kuala Lumpur office), and Research ICT Africa, Cape Town, South Africa (Dr Alison Gilldwald and Dr Christoph Stork), for allowing me to use the data for my study. I am also grateful to have been part of the research team with Arthur D. Little (ADL) for the broadband speed study. My thanks also go to Friends of Chalmers from which I received the Young Researcher Scholarship to enable me taking two internship activities in Kuala Lumpur and Cape Town.

As the Swedish education system enabled me to take some courses at other universities, I am indebted to many professors and lectures at the University of Gothenburg for sharing, in particular, their knowledge of economics and econometrics. I am thankful to Professor Lennart Flood, Professor Johan Stennek and Professor Måns Söderbom. Dr Roger Wahlberg was a very influential lecturer during my study in Sweden, and it is certainly a great loss that he passed away in peace.

My fellow researchers and students at the Division of Technology and Society were clearly the best researchers for supporting the whole educational process. I thank Professor Ilona Heldal and Dr Gustaf Sjöblom both of whom contributed discussions along the way. My fellow colleagues at the division: Orada Teppayayon, Pratompong Srinuan, Chalita Srinuan, Nattawut Ard-Paru and Chatcai Kongaut are all wonderful friends to have discussions with. Tsani Annafari was undoubtedly a friend from the very first day in Sweden. “Good luck, Pak Tsani in your future career.” Mrs Yvonne Olausson is a true mother in the corridor with much advice – not only about the study but also with hints on how to enjoy living in Sweden.

I would like to thank my fellow students at the TME department from whom I benefitted greatly during the discussions, PhD seminars and PhD workshops: Marcus Linder, Marcus Assarlind, Marcus Finlöf Holgersson, Ingo Rauth, Shahin Mokhlesian, Nojan Najafi, Levi Siljemyr and, especially, my neighbour Igor Insanic for many late Saturday discussions during the last two months. I am also grateful for all the help from Thaw Thar Minh during the broadband project and for finalizing this dissertation.

As one of my most joyful moments in Sweden was meeting up with my fellow friends from Indonesia, I thank the Indonesian Student Association (PPI Swedia). It was such a big honour to be given responsibility as head of the organization back in 2010. I thank Muhammad Azis (CTH), Erwin Hartono (CTH), Dedy Soeshandoyo (Linköping University) and Arradi Rizal (KTH).

As I was finally given the chance to stay in Sweden even longer, I thank Chalmers for giving me the opportunity to conduct research as part of my postdoc activities. Hope I can contribute to this knowledge field with the experiences I have obtained during the doctoral study.

This study could not have been accomplished on time without the continued support of my whole family back in Indonesia, the Havidzs and the Setiadis who always believed in me. To end, I would like to thank Allah Almighty for guiding me on this wonderful journey accompanied by the three most miraculous women who always give me the inspiration for why I should learn and put my foot on this earth. All my efforts and strivings are to make you happy and proud of me: my mother Hafshoh Nurdinina Shofwan, my wife Riana Garniati Rahayu and my little angel Alana Awahita Tsuraya. I love you!

Göteborg, May 2012

Ibrahim Kholilul Rohman

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List of abbreviations

ADSL	Asynchronous digital subscriber line
ArCo	Archibugi Coco
ARIMA	Autoregressive moving average
ASEAN	Association of South-East Asian Nations
DAI	Digital Access Index
DOI	Digital Opportunity Index
EC	European Commission
ENIAC	Electronic numerical integrator and computer
EU	European Union
FAO	Food and Agriculture Organization
FTTH	Fiber to the home
GCI	Global Competitiveness Index
GDP	Gross domestic product
GPT	General purpose technology
GPS	Global positioning system
ICT	Information and communication technology
IO	Input-output
ITU	International Telecommunication Union
IPTV	Internet protocol television
KAM	Knowledge assessment methodology
Mbps	Megabytes per second
MFP	Multi factor productivity
MMS	Multimedia Messaging Service
NIA	National income accounting
NIEs	The new industrial economies
OCAM	Office computing and accounting machinery
OECD	Organization of Economic Cooperation and Development
PC	Personal computer
PTS	Post- och Telestyrelsen
SIC	Standard Industrial Classification (USA)
ISIC	International Standard Industrial Classification
PDA	Personal digital assistants
QOL	Quality of life
RIA	Research ICT Africa
RIM	Research in Motion
R&D	Research and development
TAI	Technology Achievement Index
UK	The United Kingdom
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nation Development Program
USA	The United States of America
VOD	Video on demand
WB	The World Bank
WEF	World Economic Forum
WiMAX	Worldwide interoperability for microwave access

Chapter 1 Introduction

1.1. The weightless economy

A single imported greetings card with a microchip that plays Happy Birthday when the card is opened contains more computer power than existed on the planet 50 years ago. It weighs a gram or so…
(Coyle, 1997)

With the recent development of the economy, which is mainly supported by the increasing role of technology, the more conventional measurement of economic value (with weight and mass) is dematerialized (Quah, 1999). This means that, in the world of the Internet, technology seems weightless and physical distance no longer plays an important role in the transfer of technology (Keller & Yeaple, 2010). Coyle (1997) describes how the terminology of the "weightless economy" was first conceptualized taking the example of trade activities in the United Kingdom. In 1885, the country imported nearly 16 million hundredweights of wheatmeal and flour and 1.1 billion pounds of raw cotton whereas the main exports in the same year were 3.1 million tons of iron and steel and 4.4 billion yards of cotton fabrics. Using the literal concept of 'balance of trade', the volume of exported goods is scaled to that of imported goods to find the surplus or deficit of the trade activities. When the concept was used a century later, in 1985, the measurement became less relevant to evaluating trade activities because the value of computers imported into the United Kingdom was so high while the size was small and the weight low.

Coyle (1997) accentuated the shifting of products that were typically big and heavy in the 19th century (machinery, steel girders and furniture) to the miniaturization of products in the 20th century, driven by the production and consumption sides. New materials with the same value are embedded in less weight. For instance, automobiles are produced with more aluminium and plastic than steel but, at the same time, the products become much more automatic with electronic windows, power steering, Global Positioning Systems (GPS) and other supporting devices. In this regard, Wilenius (2005) mentioned that "weightless" also relates to the interests of producers and consumers alike that products become smaller and are aimed at increased usability.

Quah (1999) identifies some characteristics of the weightless economy: the increasingly dominant role of Information and Communication Technology (ICT), intellectual property, electronic media (video entertainment and broadcasting) and biotechnology (carbon base library and database). As Quah (1999) mentioned, these sectors are similar to knowledge products whose physical properties resemble those of knowledge. They are denoted for having infinite expansibility, meaning that the products are not used up physically. For instance, computer software does not lose its usefulness as more users run it: in fact, the opposite holds. This characteristic is also supported by the fact that the initial cost to develop the products is high but the cost to reproduce and distribute them is very low, hence, the marginal cost is very low or nil (Williams, 2008; Li & Shu, 2011).

Knowledge accumulation also becomes important since knowledge is conceived as a primary wealth-creating asset (Castells, 1996; Fine, 1998; Evans & Wurster, 2000). In other words, skills and innovation are seen as important elements, and high value-added activities are linked to the production of ‘‘ideas’’ rather than ‘‘things’’ (Conceicao, Heitor, Sirilli & Wilson, 2004). Drucker (1966, p. 3) also mentions that the knowledge economy is distinguished by the characteristics of the labour. Thus, unlike the manual worker who uses his/her hands to produce goods or services, the knowledge worker uses his/her head to produce ideas, knowledge and information. Tollington_(2001), and Armistead and Meakins (2002) then added that in a weightless economy, the society embodies the rise of service-based economies in which success comes not from having built the largest factory but from knowing how to locate critical pieces of information and framing the ideas that others will demand. At macro level, it is denoted by a growing and greater ratio of the weightless sector (services) to the world’s Gross Domestic Product (GDP) and from this aspect, the higher penetration of ICT supports the growth of a service economy (Antonelli, 2003).

Quah (1999) also added that the weightless economy is driven by knowledge products that disrespect geographical distance. On this issue, Addison and Rahman (2005), and Gholami, Lee and Heshmati (2006) stated that ICT (particularly the Internet, personal computers and wireless telephony) allows countries to free themselves from the domination of geographical position. With pervasive use of ICT, the products can be offered to the global market more efficiently because of cost-efficiency in regional trade integration (Epifani & Gancia, 2007). In other words, the ubiquity of ICT contributes greatly to global trade expansion and to linking nations to transnational exchanges (Dicken, 1998; Cohen, DeLong & Zysman, 2000).

To describe the size of the weightless economy in terms of intellectual property, the study by Granstrand (1999) exemplifies the importance of intellectual capital.

Table 1.1 Selected companies: market indicator and intellectual capital in 1997 (B USD)

No	Company	Market value	Profit margin	Intellectual capital	IC per employee
1	General Electric	222,748	12.3	188,320	0.9
2	Royal Dutch/Shell	191,002	8.9	114,363	1.1
3	Microsoft Corp	159,660	46.8	148,883	6.7
4	Exxon Corp	157,970	9.3	114,310	1.4
5	Coca Cola	151,288	32.1	143,977	4.8
6	Intel Corp	150,838	42.5	131,543	2.1
7	Nippon T&T	146,139	5.9	103,071	0.4
8	Merck	120,757	27.3	108,143	2
9	Toyota Motor	116,585	5.8	70,804	0.7
10	Novartis	104,468	26.5	82,036	0.9

Source: Granstrand (1999, p. 11)

Intellectual capital – measured by the ratio of market value to tangible assets – is an essential asset in selected large companies in the world as shown in Table 1.1. The proportion of intellectual capital of the market value of the company varies between 60% and 90%. When the World Bank online data set (World Bank, 2010) shows that the total GDP for 48 Sub-Saharan African countries in 1995-1996 was approximately USD 325 billion (1995) and USD 338 billion (1996), it is very easy to conclude by comparing these figures that the GDP of Sub-Saharan Africa is only 72% of the aggregate “weightless economy" consisting of the intellectual capital in General Electric, Microsoft and Shell, let alone the value of other assets.

In summary, there are many important elements to investigate in the weightless economy, but this dissertation delimits the analysis by looking at the issue in relation to the growing role of ICT sectors in daily life through the channel of producers (production) and consumers (diffusion), with the analysis investigated at micro, meso and macro level[1]. Throughout the study, the terminology of the "weightless economy" is therefore interchangeable with that of the ICT economy, as ICT is one of if not the most important element of the era (Quah, 1999). A report by the Organization of Economic Cooperation and Development (OECD) also shows the increasingly important role of the ICT sectors (2009, p. 13). ICT has been used in every aspect of life, especially when businesses transform their supply and demand chains, and their internal organization to fully exploit ICT. ICT has therefore processed creative destruction through the birth of new firms and implied greater productivity and economic growth in other sectors of the so-called General Purpose Technologies (GPT).

As Cohen et al. (2000), Jeskansen-Sundstrom (2001) and Pohjola (2002) mentioned, in relation to the terminology, the definition of the weightless economy can be given different labels, each with its own merits. The phenomenon illustrates the ongoing transformation of the economy, which is also called the 'post-industrial society', 'information society', 'innovation economy', 'knowledge economy', 'network economy', 'digital economy' and 'e-conomy'.

1.2. Framework of analysis

1.2.1 ICT production and diffusion

To investigate the impact of the ICT sectors on the economy, the demand-supply analysis can be adopted as the framework of the study, as shown in the report by the OECD (2005) and UNCTAD (2007). The demand for ICT is mainly concerned with the use of ICT products by enterprises, households and public sectors, with the data covering ICT equipment, technology capacity and barriers to use. The supply side, on the other hand, represents the data related to ICT sectors' manufacturing and trade, especially concerning the value of investment, employment and research and development (R&D) activities. To operationalize this framework, continual surveys at household and firm level are conducted, especially from the demand side, with the data on the supply side being generally more readily available.

Nevertheless, there are many challenges to conducting these surveys. The OECD (2007), for instance, described these difficulties when different industries, as part of their ICT, should have different surveys, and it is hard to compare their results. This problem relates, especially, to methodical differences between the surveys (e.g. the turnover of the wholesale trade of telephones has a different quality to the turnover of a telephone manufacturer). At a higher level of the

[1] Dopfer, Foster and Potts (2004) explain that the terminology of 'meso analysis' is related to the conceptions of market structures and industry clusters (i.e. bigger than micro but smaller than macro). The term 'meso' is also described as a way of conceptualizing the dynamic building blocks of an economic system. The analyses of industrial districts, clusters, regions, inter-firm industrial organizations, national innovations systems and networks all fall under the heading of meso economics from the evolutionary perspective. Forge, Blackman and Bohlin (2007) also describe meso-economics as economic arrangements that are not based on the microeconomics of buying and selling nor based on aggregate demand from a macroeconomic perspective. The activities can occur irrespective of level (individual, sectoral or national).

macroeconomic survey, the OECD (2007) also mentions some challenges, as the figures of national accounts are hard to calculate even on a three-digit level of industries. If the developed countries still face these obstacles, then surveys will be even harder to conduct in the developing countries where the surveys themselves generally lack reliability (FAO, 1995; Grosh & Glewwe, 1996; Vodafone, 2005; Nayar & Razum, 2006). Instead of using the demand and supply perspective, this dissertation therefore uses the framework of production and diffusion when analysing the impact of ICT sectors. This approach is still very rare, especially when it is also used to compare the phenomenon in many countries[2]. The majority of studies are carried out to investigate the production **or** consumption side separately[3].

Marcelle (2000) has drawn a general relationship between production and diffusion of ICT sectors that shows that the diffusion of ICTs is more favourable in countries that host the global ICT production networks. This means that countries are able to create wealth and produce value from service-sector activities or ICT-intensive manufacturing. Moreover, the effects on diffusion are also positive for countries that have the cultural orientation, skills and attitudes needed to enable the use of ICT goods and services as well as the time and income to access the devices for work and leisure.

With regard to the relationship between production and diffusion, Wong (2002) investigated the phenomenon of ICT production and diffusion in Asia and concluded a disconnection between production and diffusion. It has therefore been found that while the production of ICT is generally high and evolving, the region still faces a huge digital gap. Lin and Chiasson (2008) investigated the role of government policy in production and diffusion of mobile TV especially driven by its ability to allocate spectrum frequency and determine the type of technology. Murphy (2006) examined, from a different perspective, how the range of agents of ICT production and diffusion in the Gulf Arab region has sought to influence the actual impact on political space in the region.

To better describe the terminology, Jalava and Pohjola (2007) mentioned that activities in ICT production support aggregate output and thus have a significant effect on the economy by fulfilling the global market demand for exportable ICT goods and services (also echoed in the study by Wong, 2002, and Heng & Thangavelu, 2006). De Vil, Kegels and van Overbeke (2002) also defined ICT production as manufacturing industries associated with the production and distribution of ICT, following the classification of ICT products and services by the OECD, whereas in terms of the product, Lim and Wi (2001) explain that the activities mainly consist of manufacturing hardware and software.

On the other hand, the diffusion of ICT products and services defined as a process in which technology is communicated through particular channels among the members of a social system. The concept cannot be separated from the early theory of “diffusion of innovation” (Stoneman, 2002; Rogers, 2003). In this framework, the use of new technologies over time typically follows an S-curve for which the common tool of analysis is the epidemic model. The approach builds on the premise

[2] Using Scopus and Science Direct databases, it has been found that less than ten papers or studies employ production **and** diffusion in a comprehensive methodology. Many papers investigate the topic concerning the impact of ICT sectors solely from production **or** diffusion.

[3] The author has the impression that ICT production and diffusion are more loosely defined than the ICT demand and supply framework. Given the data availability, it is also more feasible to conduct the analysis based on production and diffusion framework.

that the speed of usage is limited by the lack of available information about the new technology, how to use it and what it does (Geroski, 1999). To operationalize the analysis, various models are adopted, for instance, the Autoregressive Moving Average (ARIMA) (Lee & Cho, 2007; Wu & Chu, 2010), the Logistic model (for instance, in Singh, 2008; Gamboa & Otero, 2009), the Gompetz model (Singh, 2008; Wu & Chu, 2010) and the Bass model (Michalakelis, Varoutas & Sphicopoulos, 2008).

Unlike the above analysis, this dissertation approaches the phenomenon of diffusion from an access and use analysis (Bowden & Offer, 1994; Geroski, 1999; Wareham & Levy, 2002; Hollifield & Donnermeyer, 2003). The underlying assumption of this approach is that the diffusion of innovations has happened at individual level and, hence, technology adoption is also related to a number of socio-economic characteristics such as education, income and age (Cancian, 1981). The analysis puts the characteristics of individual adopters as the main determinants and, hence, the diffusion process is not instantaneous since adopters are heterogeneous (Camerani, Corrocher & Fontana, 2010). The use of the probit model as the tool to explain the diffusion can also be found in previous studies, for instance, in David (1966, 1969), Davies (1979), Forman and Goldfarb (2005), Grazzi and Vergara (2008) and Arduini, Nascia and Zanfei (2010). Figure 1.1 describes the general framework of ICT production and diffusion used in this dissertation.

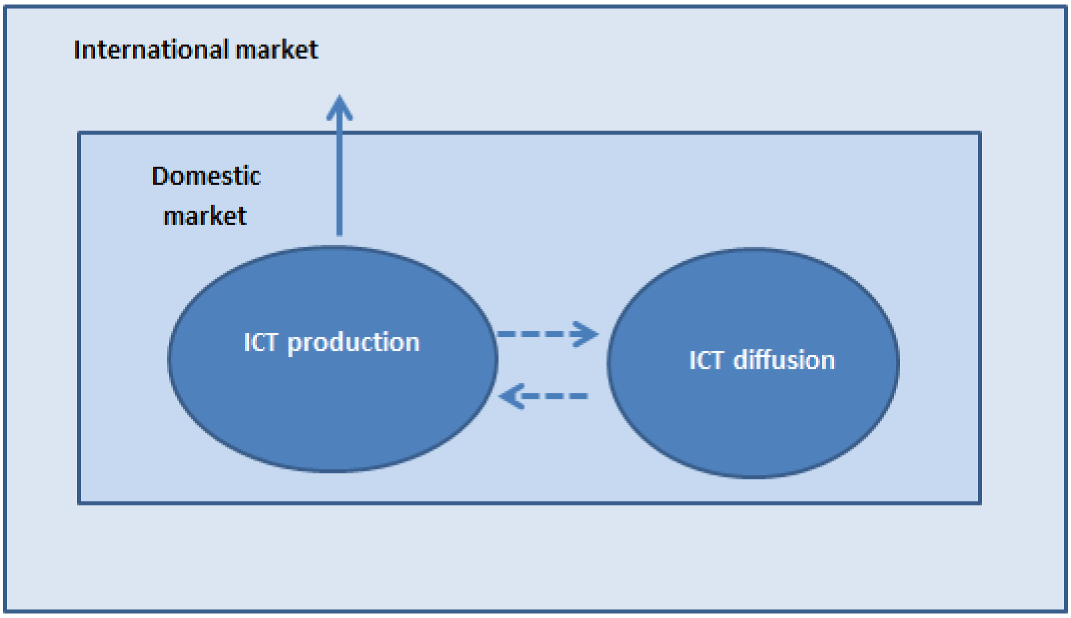


Figure 1.1 ICT production and diffusion

Figure 1.1 shows ICT production and diffusion and the relationship between them. As has been discussed, ICT production consists of manufacturing of ICT products and services (hardware and software) and the definition may follow some classification (e.g. OECD), which aims, in particular, to fill global trade. ICT diffusion explains the phenomenon of access and use of ICT in an individual level analysis. It is generally conceived that the diffusion of ICT products is affected by production, even though an empirical analysis does not always support this link. A more comprehensive and expanded framework on ICT production and diffusion is illustrated in Chapter 2 and 3.

1.2.2. ICT production and diffusion across regions

The following section discusses the underlying characteristics of ICT production and diffusion in the European, Asian and African regions. The analysis of ICT production explains how the sector currently evolves and which countries are playing a major role in the global market. In terms of diffusion, the international inequality and global digital divide in ICT has been identified as an extreme case of digital exclusion (UNCTAD, 2005). This phenomenon is mainly supported by two aspects: geographical groupings that show high dispersions among regions, and income level (Alonso, Álvarez & Magaña, 2005). The analysis to identify the problems underlying this phenomenon in each region is therefore important, as the regions are very different in terms of ICT and economic development.

In terms of production of ICT sectors, Venturini (2009) concluded that the growth impact of ICT has been particularly sizeable in the European countries, although the region seems to have lost momentum as the countries are unable to exploit the sector to increase labour productivity, which Temple (2002) addresses as the result of the lag in competitiveness due to the delayed start of ICT investment. Barrios and Burgelman (2008) addressed that the problem is due to a small amount of ICT capital in the European region. While some European Union (EU) countries, notably the Scandinavian countries, seem to be able to speed up the investment, these countries are generally relatively small so their overall influence on the EU region in general is almost undetectable. Comparing the phenomenon with that in the United States, Van Ark, O'Mahony and Timmer also identify the problem of ICT sectors in Europe driven by lower multifactor productivity. This means that the contribution of ICT to supporting the efficiency level in the production process is lower than that of the same sectors in the United States.

While there is no particular problem in relation to the basic ICT penetration rate (telephony and cellular), the European region still has a huge problem in relation to broadband adoption (Kyriakidou, Michalakelis & Sphicopoulos, 2011) with the differences in terms of economic prosperity and level of infrastructure development being among the obstacles to achieving equal diffusion between countries (Bauer, Berne & Maitland, 2002; Jakopin, 2009). Based on the analysis, which consists of 164 regions covering the EU-27, Vicente and Lopez (2006) found that the United Kingdom and Greece presented the biggest gaps within countries even though the first country is among the top ten, achieving the highest ICT progress in the region.

In Asia, the production of ICT sectors has been identified as clustered only in the leading East Asian countries (South Korea, Taiwan, Hong Kong and China), with Singapore and India recently becoming closer partners (Tseng, 2009). There is high intensity of knowledge transfer but it is limited to these countries, with each country trying to specialize in a particular ICT sector. However, while the emerging Asian economies have benefitted from ICT investment, some countries have not yet been able to do so (Wong, 2002; Ramlan & Ahmed, 2009). The problems become more serious when there is an indication that the ICT production has little or no positive spillover effects on ICT diffusion (Wong, 2002). Wong (2002) indicated that the diffusion rate of ICT devices in Asia should be greater when looking at the potential economy in the region. In fact, except for the cellular devices, the rate of diffusion is generally low. Wong (2002) concluded that the digital divide between Asian countries is even wider than that of the GDP per capita, indicating a potentially more severe digital divide in the future.

The slow emergence of socio-economic progress is another big challenge. For instance, Chatterjee, Prakash and Tabor (2004) found that when using the poverty line of 1 USD/day there were still 700 million poor people on the Asian continent in 2000, a fall from the previous figure of 800 million. Friel and Baker (2009) discovered that the life expectancy rate for all the Asia Pacific countries increased significantly during 1990-2008 but that the distribution between the countries is not uniform. Japan, Taiwan and Korea have an average life expectancy of 82 years while Lao, Myanmar and even Cambodia have a rate of only about 60 years. The study also found that by grouping the population based on quintiles, the richest quartile in India is vulnerable to the risk of the under-five mortality rate of about 40%, which is equal to that of the rich in the poorest quartile in Vietnam. Based on this evidence, it would be an important question whether the development of ICT sectors has contributed to the socio-economic variables in Asia.

In Africa, Joseph and Gillies (2009) stated that if the basis of the explanation of globalization is the relationship to the international economy, then the central paradox in the African context tells the story that by the early 1990s, Africa's relationship with the international economy was mainly due to or mediated by public aid flows. It began even before some African countries gained their independence with some philanthropic programmes initiated by donors, creating stagnation, distortion or even contraction of economic growth in the African region. As a result, Joseph and Gillies (2009) show that one sixth of the bottom billion do not benefit from the current expansion of the economy with half of that bottom billion identified as Sub-Saharan African countries.

In view of ICT production, Soderbaum and Taylor (2008) stated that most African countries exploit their human capital too little for the development of science and technology. It becomes contradictory because the region should attempt to leverage the level of human capital considering that most African countries are dealing with technology transfers and acquisition of imported technological products from other countries (Senghor, 2000). A case study in Tanzania, for instance, shows that public companies in capital-intensive industries that predominantly use imported technological products from the rest of the world contribute little to the growth, employment and regional quality that typify the public enterprises in Africa (James, 1995). There is therefore still slow emergence of economic progress benefitting the development of ICT sectors (ITU, 2009; Aker & Mbiti, 2010).

On the diffusion side, the African region has an even greater variety of challenges due to differences in terms of the physical, political and economic landscape (Joseph & Gillies, 2009). Under-capacity in telecommunication has been a problem of African countries, for instance, as shown in Nigeria, a country in which only six cities (of the fourteen most populous) have international direct dial. In Egypt, where a quarter of households have a phone connection, the waiting list for access was still at 1.2 million over the last decade. External factors (civil war) also greatly contribute to the slower rate of telecommunication infrastructure. For instance, as a result of the civil war in Congo, teledensity has declined to only 0.04%, which was the lowest for the African countries by the end of 2000. The political situation is also crucial as shown in South Africa. By the mid-1990s, the country had the highest teledensity of the African countries reaching 10% of the penetration rate. At that time, the penetration rate was unequally distributed with 64% in white areas and less than 1% in rural black areas (Carmody, 2010).

The central question for the African region is thus also similar to that in Asia and it will be directed to answer whether the current development of ICT sectors (mainly the diffusion of cellular devices and Internet) has been able to improve the quality of life (QOL) where ICT production is still out of reach to contribute to the economy.

1.3. Purposes and research questions

The dissertation aims to achieve the following main purpose:

To identify the problems faced by the European, Asian and African regions concerning the production and diffusion of the ICT sectors.

Taking the purposes as the point of departure, the main research questions built into this study is:

What is/are the specific problem(s) concerning production and diffusion of ICT sectors faced in the European, Asian and African regions? In what ways can one or more strategies address these problems?

The question is first concerned with the identification of problems in ICT sector production. In the case of Europe, the question is investigated by calculating the contribution by ICT sectors to the economy in terms of output, using multiplier analysis to show how the change in the ICT sectors' final demand contributes to the enlargement of the economy. To give a better perspective on this measurement, a comparison between ICT and non-ICT sectors is also employed to distinguish the relative position of the ICT sectors. The decomposition analysis is also employed to see whether the change in output has been affected by the domestic final demand effect, export effect, import substitution effect and technological change effect. This research question aims to point out the most important decomposition factor as well as discover which decomposition factors have to be considered further. Equally important, it addresses the problem on diffusion in relation to the broadband gap and demand-side analysis taking Sweden as a case study. This problem becomes important since broadband is seen as the means for enabling the transformation of the region towards a knowledge society, yet, the region still has severe disparities concerning the broadband penetration rate.

In the regions of Asia and Africa, the central issue is linking ICT diffusion to the socio-economic variables. To operationalize this investigation, a set of unbalanced panel data in Asia will be investigated through a panel cointegration model to see whether the development of ICT sectors (mainly telephony, the Internet and television) has contributed to improving the socio-economic variables (education and health). A similar aim is applied in Africa but with a different methodology. A set of household data comprising 20,000 observations in 2008 is investigated to see whether access to a cellular device can improve quality of life (in terms of income, productivity and decision making). On the production side, the problem of a low impact of ICT investment in some Asian countries is also addressed taking Indonesia as a case study. This case is presented to answer the question of why some countries in Asia are not yet able to obtain greater impact from ICT investment.

The investigation regarding ICT production in the European region and (a case study in) Asia is conducted employing the input-output (IO) methodology. The same aims and methodology can be seen in Timmer and Ark (2005), Jalava and Pohjola (2007), De Backer and Yamano (2007), and Wan, Xuan and Lv (2011). The analysis on the diffusion is mainly approached from an individual level. Thus, the analysis focuses on the characteristics of individual adopters as determinants of adoption and assumes that the diffusion is not instantaneous as adopters are heterogeneous (Camerani et al., 2010). The study uses the probit model as the tool to explain the diffusion, as was also done in older studies (David, 1966, 1969; Davies, 1979) and more recent ones (Forman & Goldfarb, 2006; Grazzi & Vergara, 2008; Arduini et al., 2010). The framework of the analysis can also be found in Bowden and Offer (1994), Geroski (2000) and Wareham and Levy (2002).

The detailed derivation of the sub-research questions assigned to each region is explained in Chapter 3.

1.4. Scope and limitations

By retrieving current studies in the literature, it was found that there is no strong consensus on how the terminology of ICT is defined. When referring to this concept, some studies approach the analysis based on "sector" investigation, whereas others refer to "product" or "device". The other studies do not exemplify the terminology but rather provide the boundary of definition. For instance, "ICT sectors" can be identified in terms of technicality; the sectors should then be termed high-technicality activities (Deakins & Hussain, 1993). "ICT products" exhibit fixed entry costs and low marginal costs (Varian, 2001), with recovery of the fixed entry costs being very difficult (Koski & Majumdar, 2002) as a result of the high level of R&D activities and the degree of uncertainty (Aoun & Hwang, 2008). Some studies define ICT in relation to the level of innovation, for instance, based on studies of Helpman (1998) and Freeman and Louca (2001), Antonelli (2003) mentioned that ICT is a general purpose technological system with all the characteristics of a radical innovation. ICT is also a superior technology worldwide in a great array of product and factor markets.

De Vil et al. (2002) characterized the ICT market as heterogeneous, thus, to sustain competitiveness, producers attempt to create attractive conditions in which strong R&D capacities, qualified labour forces and easy access to venture capital are available. Hence, with regard to the labour market in the ICT industry, Grabowski (1968) shows that firing and rehiring is very costly because the firms are highly technical, thus, even educated workers require firm-specific knowledge and training. The experience of the firm's knowledge base may be lost or even transferred to competitors if the (skilled) labour is fired. These characteristics justify the later finding that ICT production is generally clustered in specific countries.

Indexes are also being used when investigating ICT. Alvarez and Magana (2008) summarized how the indexes evolved. For instance, the World Economic Forum's (WEF) technological indexes measure Internet access, telephone mainlines and personal computers (PCs) as well as some other categories that represent innovative capacities and technology transfers (WEF, 2002, 2004). The WEF has also introduced the Global Competitiveness Index (GCI) to define a comprehensive set of technological and innovation factors that drive countries' overall efficiency and competitiveness including the ICT components, such as cellular telephones, Internet users and PCs as well as innovation components, like the availability of scientists and engineers, utility patents and intellectual property protection. Next, the ArCo index is built based on innovative activity, measured by patents and publications, as well as several human capital indicators: tertiary science education, years of schooling and literacy rates (Archibugi & Coco, 2004, 2005).

The other index can be in the form of the *Knowledge Assessment Methodology* (KAM) by the World Bank, which represents the overall level of development of a country or region in the knowledge economy. The Digital Access Index (DAI), created under the auspices of the International Telecommunication Union (ITU), also tries to reflect ICT access and use the capacities of the population of a country. The United Nations Development Programme's (UNDP) Technological Achievement Index (TAI) composed the "diffusion of newest technologies" index based on Internet hosts and medium and high technological content exports besides the "diffusion of oldest technology" in which telephone mainlines and electricity consumption are considered. These two categories are combined with another two, one related to the creation of technology, based on patents, royalties and license fees, and the other related to human skills.

Knowing that there are many possible meanings when defining the term 'ICT', the dissertation first tries to identify the exact meaning of this concept from previous studies. The definition is delimited to only journal articles published after 1996 based on the Scopus database[4]. The summary of this analysis is presented in Table 1.2.

[4] There are 14,500 articles with "ICT" in their studies, but after delimiting the searching to only the "economic, econometrics and finance" subject area, the number of articles was reduced to only 610 by April 9th, 2012. The exercise is only applied to papers mentioning "ICT" or "Information and communication technology" in their title and not the other variations/derivations of it (e.g. information technology). The definition of ICT could thus clearly be obtained from other papers without "ICT" in the title. The terminology could also refer to ICT when the authors mention similar topics (e.g. "post-industrial society", "information society", etc.). However, it is assumed that the title of the papers indicate the topic precisely and quickly in attempts to communicate the aim(s) (Björk & Räisänen, 2003, p.224).

Table 1.2 The various definitions of ICT

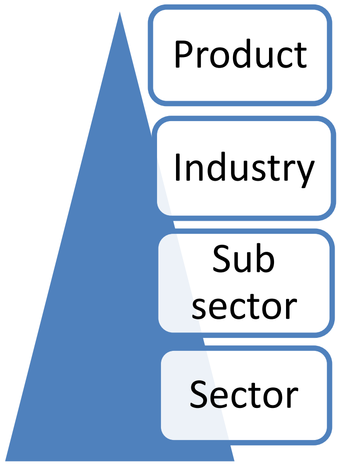
Definition of ICT	Remarks	Authors
As sector/industry	OECD category	Pilat, Ahmad and Schreyer (2004); Cette, Lopez and Noual (2005); Pilat (2005); Lind (2008); López-Pueyo, Barcenilla-Visús and Sanau (2008); Aoun and Hwang (2008); López-Pueyo, Sanau and Barcenilla (2009); López-Pueyo and Mancebón (2010); Giotopoulos and Fotopoulos (2010); Okon-Horodynska, Wisla and Sierotowicz (2011)
	Based on ICT-producing and ICT-using sector	Stiroh (2002); Dahl, Kongsted and Sørensen (2011); Barrios and Burgelman (2008); Koski, Rouvinen and Ylä-Anttila (2002)
	Refer solely to telecommunication sector	Gholami et al. (2006); Samoilenko and Osei-Bryson (2008); Hallikas, Varis, Sissonen and Virolainen (2008); Yu, Suojapelto, Hallikas and Tang (2008); Kushida (2012)
Industry and firm	The ICT industry is typically high risk and high return whereas an ICT firm is defined as a technology- and knowledge-intensive firm	Houben and Kakes (2002); Torrent-Sellens and Ficapal-Cusí (2011)
As index[5]	Digital opportunity index (DOI)	Samimi and Ledary (2010)
As product	Internet	Cuadrado-Roura and Garcia-Tabuenca (2004); Hollenstein (2004); Haugh and Robson (2005); Fabiani, Schivardi and Trento (2005); Thulin and Vilhelmson (2005); Bozinis (2007); Touati (2008); Lopez-Nicolas and Meroño-Cerdán (2009); Franklin, Stam and Clayton (2009); Corrocher and Fontana (2008); Nurmilaakso (2009); bin Ibrahim, Ainin and Faziharudean (2009); Arvanitis and Loukis (2009); Hassan, Shaffril, D'Silva, Omar and Bolong (2011); Biniazi, Ghahremani, Alipour, Soofi and Akhavan (2011); Martin (2011); Cortés and Navarro (2011); Dede, Kamalakis, Varoutas, Fuentetaja and Javaudin (2010); Haller and Siedschlag (2011)
	Computer (or software)	Howells (1995), Erumban and de Jong (2006); Gago and Rubalcaba (2007); Jalava and Pohjola (2008); Lucas (2008); Moshiri and Simpson (2011); Giuri, Torrisi and Zinovyeva (2008); Collard, Fève and Portier (2005); Van Der Laan, Van Oort and

[5] The majority of the studies employing the index can be found in reports published by international organizations (the World Bank, ITU, etc.)

		Raspe (2005)
	Cellular	Cocosila and Archer (2010)
Combination of products	Computer and Internet	Burke (2009); Krizek and Johnson (2007); Verdegem and De Marez (2007); Grazzi and Vergara (2011); Salehi and salehi (2011); Spiezia (2011); De Vries and Koetter (2011)
	Fixed and mobile telephony, computer and Internet	Friis (1997); Barilli (1999); Inklaar, O'Mahony and Timmer (2005); Lio and Liu (2006); Gani and Clemes (2006); Vicente and López (2006); Shamim (2007); Malanowski and Compaó (2007); Álvarez and Magaña (2008); Gaiani (2008)
	Telecommunication, software and hardware	Colecchia and Schreyer (2002); Bassanini and Scarpetta (2002); Oulton (2002); Becchetti, Londono Bedoya and Paganetto (2003); Bugamelli and Pagano (2004); Bakhshi and Larsen (2005); Giaoutzi and Vescoukis (2006); Forge (2007); Mathur (2007); O'Mahony, Robinson and Vecchi (2008); Kuppusamy, Pahlavani and Saleh (2008); Venturini (2009) – plus office machinery -- Martínez, Rodríguez and Torres (2010); Cooper and Madden (2010)
	Telecommunication, software, hardware and electronic product	Beretti and Cette (2009)
	Radio, television and communication equipment	Edquist (2005); Bocquet and Brossard (2007)
Others	Semi-conductor	Ning (2008)
	Computer installed, book values of office, computing and accounting machinery (OCAM) from balance sheets or investment in ICT	Hempell (2005)
	Patent	Corrocher, Malerba and Montobbio (2007); Antonelli, Krafft and Quatraro (2010); Tseng (2009)

Table 1.2 shows that previous studies employ various definitions when explaining ICT, from sector, industry, firms, devices and index. In terms of sector, the majority of the study refers to the OECD definition of ICT sector classification, whereas in terms of the product or combinations of products, computers and the Internet are the most common features. The least-used definition of ICT is related to patents and semi-conductors. This taxonomy then justifies that a particular ICT sector or certain ICT products and/or services can be used to represent the discussion on behalf of ICT as also found in some of the appended papers in this dissertation.

With the benefit of the classification in Table 1.2, this dissertation also adopts layer analysis when investigating the impact of ICT. This means that the ICT economy is evaluated in terms of sector, sub-sector, industry, and products or devices. Since the definition of "sector" may also vary between the studies, this dissertation is based on Elliott and Lindley (2006a, b), and Spatareanu (2008) who define a "sector" as the one-digit level of the Standard Industrial Classification (SIC), whereas "industry" and "sub-industry" are classified based on the two-digit and three-digit SIC classification. This dissertation also adopts Bernard, Redding and Schott (2010) when referring to "product" and "good" based on a five-digit SIC category. Figure 1.2 illustrates the ICT definition based on layers.[6] The further analysis of different dimensions of methodology, time frame and region is elaborated on Chapter 4.



Type	Region/country	Paper(s)
Cellular Internet/ Broadband	Sweden Europe (OECD) Indonesia	5, 6, 9, 10 4, 8
IPTV	Europe	11
Media and content	Europe	3
ICT sectors Telecommunication	Europe Indonesia	1, 2 7

Figure 1.2 Appended papers and different ICT layers

Some appended papers adopt different layers and terminology when defining ICT, but a more precise classification of ICT sectors is presented in Papers 1, 2 and 3 investigating the case of the European region based on the OECD (2009) definition. The classification is motivated with the need for statistics and analysis to support a common statistical standard that can be used uniformly to

[6] The classification of ICT based on the sector and sub-sector is employed for the studies in the European region using the OECD (2009) classification. Moreover, telecommunication is seen as a single sector from its manufacturing classification, which has the SIC code 48, while as service sectors, telecommunication operators are categorized in 481312 (cellular products). The IPTV is categorized as industry, for which the SIC code is 3663.

evaluate the information society within the OECD countries (OECD, 2009). In this regard, two categories are attributed to the ICT sectors: ICT product and media, and content product.

"ICT products must primarily be intended to fulfil or enable the function of Information processing and communication by electronic means, including transmission and display, whereas, content corresponds to an organized message intended for human beings published in mass communication media and related media activities. The value of such a product to the consumer does not lie in its tangible qualities but in its information, educational, cultural or entertainment content"
(OECD, 2009)

OECD then defines ICT products as classified in Table 1.3.

Table 1.3 Classification of ICT products

ISIC-4 digit	Definition
2620	Computer and peripheral equipment
2630	Communication equipment
2640	Consumer electronic equipment
2610,2630, 2680	Miscellaneous ICT components and goods
2610,2630, 2640, 2680	Manufacturing services for ICT equipment
5820	Business and productivity software and licensing services
6202	Information technology consultancy and services
6110, 6120, 6130	Telecommunications services
7730	Leasing or rental services for ICT equipment
9511, 9512	Other ICT services

Source: OECD (2009)

The code ISIC may correspond to many ISIC categories; hence the above classification is based on the dominant group within each category of ICT products. In addition to the ICT products, the media and content products correspond to the following classification in Table 1.4.

Table 1.4 Classification of media and content products

ISIC	Definition
5811	Printed and other text-based content on physical media and related services
6010, 6020	Motion picture, video, television and radio content, and related services
5911, 5912	Music content and related services
5820	Games software
5812	On-line content and related services
7310, 6391	Other content and related services

Source: OECD (2009)

To operationalize the analysis based on the IO method, it has to be assured that the definition of 'ICT sector' based on the OECD table is compatible with national income accounting (NIA) based on the Eurostat. Table 1.5 below shows the ICT sectors based on the NIA category adopting the OECD framework.

Table 1.5 Classification of ICT sectors based on the 59 sectors in the European IO table

Sector number	Sector name
16	Printed matter and recorded media
23	Machinery and equipment
24	Office machinery and computers
25	Electrical machinery and apparatus
26	Radio, television and communication equipment and apparatus
27	Medical, precision and optical instruments, watches and clocks
36	Wholesale trade and commission trade services, except motor vehicles and motorcycles
43	Post and telecommunications services
49	Computer and related services
50	Research and development services
51	Other business services
53	Education services

Table 1.5 shows that there are 12 ICT sectors among the 59 sectors in the European IO table of ICT products, and media and content products. Thus, the economic impact and the contribution of the ICT sectors in this study (Papers 1, 2 and 3) correspond to these 12 sectors. However, since the aggregation level of the ISIC categories are more detailed than the IO categories, some ICT products, and media and content products are aggregated in a particular IO sector in Table 1.5.

There are also some delimitations concerning the regions investigated in the study. The 'European countries' in this dissertation (Paper 1, 2, 3, 11) only represent selected countries in Europe and refer to a list of countries that are identified as having long histories of R&D activities and technology transfer (Eichengreen, 2008, p. 26, Table 2.6). The list of countries therefore consists of Austria, Belgium, Denmark, Finland, France, Germany, Italy, the Netherlands, Norway, Spain and Sweden. A study of OECD countries (Paper 4) is also used to represent the European region[7].

The Asia region in the study (Paper 9) employs data that cover roughly 35 selected Asian countries, representing all the sub-regions in Asia based on the World Bank and International Telecommunication Union's (ITU) database. There are about 52 countries in Africa, while in this dissertation, Paper 10 uses the household survey data carried out by the Research ICT Africa (RIA) in 14 countries (Senegal, Burkina Faso, Benin, Côte d'Ivoire, Zambia, Mozambique, Tunisia, Uganda, Tanzania, Kenya, Ethiopia, Ghana, Namibia and South Africa).

The dissertation and appended papers adopt various methodologies and types and sources of data. Even though the whole analysis is aimed at identifying the problem of ICT production and diffusion in

[7] The history, which dates back to 1960, shows the prominent role of the European countries when 18 European countries plus the United States and Canada joined forces to create an organization dedicated to global development. Today, out of 33 OECD members, 23 countries are European (EU15 plus the Czech Republic, Hungary, Iceland, Norway, Poland, the Slovak Republic, Switzerland, Turkey).
Retrieved from http://stats.oecd.org/glossary/detail.asp?ID=1884

the European, Asian and African regions, the time series between papers are not always linked apple to apple. For instance, the investigation into ICT production in Europe is based on macro-level data (IO table) corresponding to 11 countries, with the data ranging from 1995 to 2005, whereas, the papers that discuss ICT diffusion apply the micro-survey data in recent years (2010-2011) to a specific country that is taken as a case study. The same limitation is also found in Asia where the ICT production uses a wide range of panel data models, while the ICT diffusion employs the survey data for a country. These limitations are attributable to data availability and are discussed further on Chapter 4. Moreover, Figure 1.3 maps the regions and countries investigated in the study.

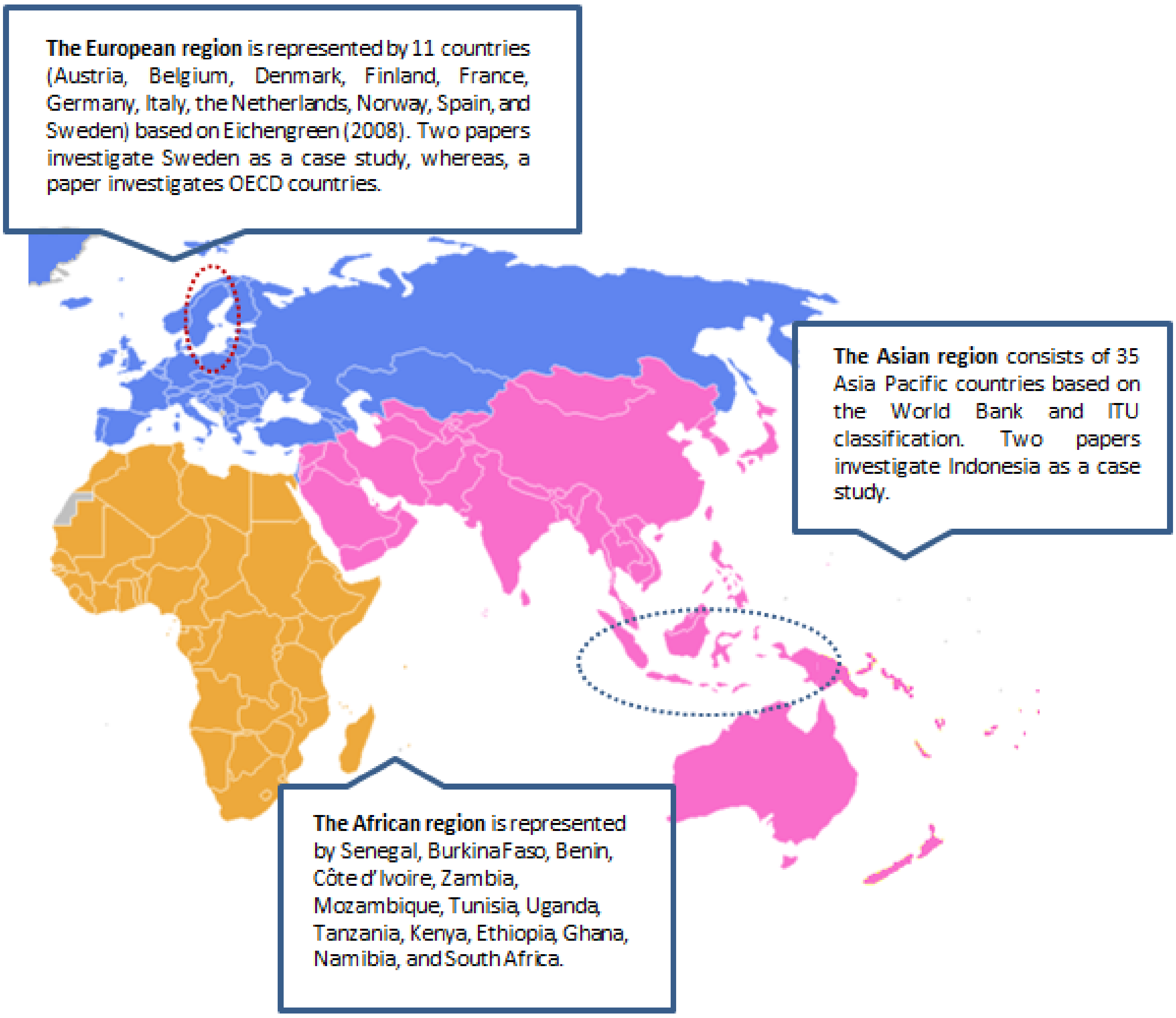


Figure 1.3 Map of the regions and countries investigated in the study

1.4. Important terminologies

The dissertation contains some important terminology for the purpose of the study and to answer the research questions. The following section defines these terminologies.

Cellular — A device that allows calls to be made and received over a radio link while the users are moving around a wide geographic area. The device is connected to a cellular network provided by operators. This dissertation uses the terminology of 'cellular' and 'mobile' phone interchangeably.

Cointegration	Refers to the process showing the convergence of the two non-stationary series in the long run.
GPT	Abbreviation of General Purpose Technology, which refers to the potential for pervasive use of technology in a wide range of sectors; hence, technological dynamism enables generalized productivity gains transferred to the rest of economy. The concept is also linked to 'innovational complementarities'.
ICT diffusion	Refers to the process of how ICT products and services are being accessed and used by the end-users. Adoption is part of ICT diffusion. In this study they are used interchangeably.
ICT production	Refers to all the activities in the manufacturing of ICT products based on certain definitions (e.g. OECD, 2009) that commonly consist of manufacturing of hardware and software products.
Information society	Refers to a phenomenon that results from the role of ICT in every aspect of life, especially its economic and social implications.
Input-output	Depicts the transaction flow across sectors, with each sector producing a certain output and, at the same time, consuming input from another sector. The table consists of three main quadrants. The first quadrant describes the inter-linkage between sectors in what is known as an intermediate transaction, while quadrants II and III are the final demand and primary input, respectively. Since the sectors are producing and consuming a particular output from other sectors at the same time, the intermediate transaction in quadrant I indicates the intermediate demand that reflects the flow of intermediate output and input, and interrelatedness between the sectors.
Knowledge economy	Refers to the state of the economy that concerns the ability of technology and ICT to create a higher level of human capital.
Output	Refers to the summation of intermediate and final demand. Based on the IO framework, the amount of output equals the input. A common characteristic is that output is larger than GDP due to the value of imports.
Output multiplier	Refers to the amount of output change as the impact of the change on final demand.
Panel data	Refer to the data consist of both time series and cross-sections.
Weightless economy	Denotes a society in which technology has an increasing role and the more conventional measurements of economic value (weight and mass) are dematerialized.

1.5. Outline of the dissertation

The following section is an introductory chapter. Chapter 2 summarizes the previous literature studies, the role of technology and ICT, in particular in the development of the economy. As the emphasis of the thesis is to identify the problem of production and diffusion of ICT sectors in each region, Chapter 3 pictures state-of-art data and previous empirical studies on the role of ICT in each region. Chapter 4 explains the methodology used in the dissertation and the appended papers and deals mainly with the presentation of the input-output (IO) methodology and selected econometric tools. Chapter 5 discusses the empirical analysis of the study. Chapter 6 synthesizes the study into summary, discussion and future studies. Table 1.6 shows the main focus of each chapter.

Table 1.6 Main focus of each chapter

Chapter	Main focus
Chapter 2 **The important role of Information and Communication technology**	This chapter presents the importance of technology in the development of the economy from a general perspective. The chapter then narrows down the analysis to discuss the importance of ICT sectors based on previous studies. Examples of cellular devices, computers, Internet and broadband are given.
Chapter 3 **ICT economy across regions**	This chapter discusses relevant empirical studies and previous literature on the impact of ICT sectors in each region. The studies are framed based on ICT production and diffusion.
Chapter 4 **Methodology and data**	This chapter presents a summary of methodology in the appended papers. In this context, the IO analysis and some econometric methodologies are discussed.
Chapter 5 **Empirical results**	The chapter elaborates on the empirical analysis of the study covering two main aspects: identification of the problems of ICT production and diffusion in each region.
Chapter 6 **Summary of the study**	This chapter concludes the study, states the contribution and limitation and gives the direction for future research.

Chapter 2 The important role of Information and Communication Technology (ICT)

This chapter presents the frame of reference for the whole analysis in the dissertation. It elaborates on existing literature, discusses the importance of technology as a general purpose technology (GPT) and the Information and Communication Technology (ICT) sectors in particular and frames the analysis based on ICT production and diffusion.

2.1. Technology and human capital

Traditional economic growth theory pays little attention to the role of technology and human capital in catalyzing economic growth[8]. Koopmans (1963) argued that the attention of previous growth theory focused more on the role of savings and distribution of wealth. For instance, there was a debate on where and at what level optimal economic growth should be sustained. Bauer (1957) favoured a balance of welfare between current and future generations showing a need to set the level of savings by individuals and tax charges by the government. In this discourse, Ramsey (1928) and Harrod (1948) placed equal weight on welfare in each period, contrary to Allais (1947), who suggested that the welfare level is different in every context. Consequently, the welfare level is subject to ethical and political considerations that make no sense to control the level and restrain individual behaviour. In summary, there was a tendency for early discussions on economics literature to neglect the role of technology and human capital but consider saving as the engine of growth up to the early 1950s.

Technology, human capital and skills were later identified as important factors to support economic growth during the 1960s. Quah (1999) mentioned that Arrow (1962) was among the first economists to be aware of the existence of knowledge as an economic commodity. Knowledge displays infinite expansibility; hence, the consumption of such a commodity will not reduce the physical functionality of the original nor be affected by the barrier of physical distance. Whereas Scherer (1999) stated that Schultz (1961) first introduced the terminology of “a new paradigm of economic growth” when suggesting the importance of human capital, Schultz (1961) stated that despite massive destruction of physical capital during the post-World War II period in Germany, something was not destroyed, namely experience and accumulated skills that made the country rebound afterwards.

The extensions of the study place importance on technology and human capital evolved in the 1980s, for instance, in Romer (1986) and Madisson (1991). Romer (1986) incorporated a knowledge factor as an input to the production function and found that the growth model generated different results compared with the traditional diminishing returns of the production function. In other words, the use of technology supports increasing return to scale for many production processes (Milgrom, 1991). Following this study, Romer (1990) added that the additional portion of human capital consisting of research and development is a stronger determinant of the rate of growth. This conclusion was also found in the study by Lucas (1988), which explained the role of human capital in sustaining the level

[8] Ben-David and Loewy (1998) mentioned that, among others, the Solow model, Cass and Koopmans are grouped under “traditional view on economic growth theory” when investigating the impact of free trade on reducing income disparities between countries.

of economic growth in the long run. The role of human capital and an educated population are thus crucial as determinants of economic growth. This factor is visibly strong in some other studies, for instance, those of Barro (1991), Mankiew, Romer and Wreil (1992), and Levine and Renelt (1992).

In parallel with the theoretical studies conducted by Romer (1986, 1990), Barro (1991) investigated a comparative study of 98 countries during the period 1960-1985. The study concluded that the poorer countries can only catch up with the richer countries if the former can reach a higher level of human capital. In relation to this, Madisson (1991) added that there are only three countries that have been categorized as leaders in technological innovation in the last three centuries: the Netherlands, the United Kingdom and the United States. As a result, the growth rates of these leading countries are always higher than those of any other countries.

Technology became more important following the conception of general purpose technology (GPT). This view is characterized by the potential for the pervasive use of technology in a wide range of sectors; hence, technological dynamism enables generalized productivity gains transferred to the rest of the economy. The concept is also linked to "innovational complementarities" in which productivity in the downstream sector increases as a consequence of innovation in GPT (Rosenberg, 1982). In relation to this, Steindel and Stiroh (2001) concluded that a major source of improved aggregate performance has been driven by high technology sectors. Faster productivity growth in this rapidly growing sector has directly added to the aggregate growth and a massive wave of investment in high tech by other sectors.

While human capital, skills accumulation and technology together contribute to economic growth based on previous studies, Gould and Ruffin (1993) point out the superiority of technology stating that this variable increases the level of human capital and education and, thus, accelerates the convergence of economic growth. Technology is therefore no longer seen as a traditional investment but, as Bresnahan and Trajtenberg (1995) assert, the role of technology has become more important as a catalyst in the process of innovation. Tightly linked to this view, Scherer (1999, pp. 33-36) emphasizes that the future of economic growth depends on how a country raises the level of innovation in which technological development in terms of research and development (R&D) plays an important role.

At industry level, Athey and Stern (1998) found similar conclusions, indicating the importance of technology. The study found complementarity between information technology, organizational factors and economic performance. In line with this study, Brynjolfsson and Hitt (2000) found that the increase in the level of technology capital in an economic sector is associated with the reduction in vertical integration and lower costs of coordination. The contribution of information technology can therefore be addressed by the creation of a new business, new skills and new organizational and industry structures. Baily and Lawrence (2001) pointed out that purchasing of IT significantly affects the total factor of productivity, in particular, the service industry. Innovation in the IT sectors greatly improved economic performance in recent expansions, affecting both old and new firms.

In an empirical analysis, a study by Hall and Mairesse (1993) investigates a production function in France. The manufacturing sectors are based on unbalanced panel data from 1980-1987. Of these firms, 210 had R&D information back to 1971. The results confirm the positive feedback and contribution of IT in raising the efficiency and productivity level. The study found that the return of

R&D activities ranged from 6 to 7%. Similar studies can be found in Mairesse and Cuneo (1985), Griliches (1980, 1986), Cuneo and Mairesse (1984), and Griliches and Mairesse (1983).

This dissertation employs a framework that draws on the importance of technology in supporting human capital, innovation and its role in GPT, in which ICT sectors embedded these characteristics and, hence, were best suited to depicting technological development. The sectors have contributed to the process of creative destruction through the birth of new firms and implied greater productivity and economic growth in the other sectors following the nature of GPT (OECD, 2009). In the report for the World Economic Forum (WEF, 2009), Kramer, Jenkins and Katz also refer to the role of ICT sectors when explaining the technology sector.

2.2. ICT production and diffusion

2.2.1. ICT production

The production of ICT goods and services has been one of the fastest-growing activities in the world. By the end of the 2000s, the activities had contributed more than 7% of business GDP in the OECD zone. The sector is even more promising because, despite stock market fluctuations, the ICT-producing sectors have constantly stimulated economic growth and generated productivity gains (De Vil et al., 2002). Gaspar (2004) discussed the nature of ICT production explaining that the sectors generate productivity growth through chains. The sectors are capable of increasing their own productivity growth, increasing ICT per worker from capital deepening and contributing to other sectors through spillover effects and externalities (mainly via savings on transportation and searching costs). When defining the process, Lim and Wi (2001) explain that ICT production refers mostly to manufacturing of hardware and software, with the first concerning production of ICT goods such as integrated circuits (ICs), memory chips, electronic equipment (e.g. cellular telephones and personal digital assistants [PDA]), accessories and peripherals (e.g. printers, scanners and modems). Later, software production involves the creation of applications, system development, database programming and content development.

The role of the ICT sectors in economic growth is explained by Jalava and Pohjola (2007) in a more thorough exposition as a process in which the sectors provide output for end-users and, at the same time, inputs for other sectors. Jalava and Pohjola (2007), based on Jorgenson, Ho and Stiroh (2003), identified how the ICT sectors contributed to economic growth based on the production possibility frontier as the basic formulation.

$$Y\left(Y_{ICT}(t), Y_0(t)\right) = A(t)\, F(K_{ICT}\,(t), K_0\,(t), L(t)) \qquad (2.1)$$

From equation (2.1), at any given time, t, the aggregate value added, Y, is assumed to consist of two products from the production of ICT sectors (Y_{ICT}) and non-ICT sectors Y_0. The products are produced from the inputs, which consist of ICT capital (K_{ICT}) and non-ICT capital K_0 as well as labour L. From equation (2.1), $A(t)$ represents multifactor productivity or the level of technology used in the production function. It is also called the residual, denoting the efficiency level of a production function (Van ark et al., 2008).

In terms of percentage change, equation (2.1) can then be transformed into equation (2.2):

$$\ln Y = \overline{w}_{ict} \ln Y_{ICT} + \overline{w}_0 \ln Y_0 = \bar{v}_{ict} \ln K_{ICT} + \bar{v}_0 \ln K_0 + \bar{v}_L \ln L \qquad (2.2)$$

Equation (2.2) is the other representation of the production function and consists of ICT and non-ICT products. The weights $\overline{w}_{ict}, \overline{w}_0$ in equation (2.2) depict the average nominal output share of ICT and other production where the sum of these two equals zero. Likewise, the sum of $\bar{v}_{ict}, \bar{v}_0, \bar{v}_L$ also equals zero, which represents the average nominal income shares of ICT capital, other capital and labour. The average number is taken from periods t and $t-1$.

From equation (2.2), it can be derived that the impact of ICT can be traced from three sources: (i) the direct contribution of ICT production, (ii) the contribution of ICT capital as input to the production, and (iii) multifactor productivity (A), where $\Delta \ln A = \overline{w}_{ict} \ln A_{ICT} + \overline{w}_0 \ln A_0$.

2.2.2. ICT diffusion

To start this sub-section, the relationship between diffusion and its related terminology, adoption, is presented. Abera (2008) summarized extensive literature studies on the difference between adoption and diffusion stating that both concepts are distinctive yet interrelated. Adoption relates to the decision to use new technology on a regular basis whereas diffusion refers to the spatial and temporal spread of new technology. In view of this, Abera (2008) stated, based on Rogers (1983), that while adoption refers to the decision on whether to use new technology, diffusion is seen as a greater phenomenon and is thus called aggregate adoption (also echoed by Feder, 1985; Thirtle & Ruttan, 1987). Diffusion is defined as a process in which technology is communicated through particular channels among the members of a social system.

There are, therefore, four elements for this process to happen: (i) technology that contains a new idea or object to be diffused, (ii) communication channels on the way information is transferred, (iii) a time period during which the process is diffused, and (iv) a social system, which according to Knudson (1991) refers to the individual, organization and any other institution with its adopting strategies and, according to Rogers (1983), is defined as a set of inter-related agents that share a common problem and cooperate to achieve their goal. Similarly to the distinction by Roger (1983), Feder (1985) defined (individual) adoption as the process in which agents use technology in the long run, benefitting from the full information enabling them to use it, whereas diffusion (aggregate adoption) is the spread of technology in certain geographical areas and populations. This dissertation emphasizes the phenomenon in a large population, which is related to aggregate adoption. However, this dissertation sees the processes as inter-related and uses the terminology interchangeably, as also found in many recent studies (Munkvold, 1998; Schreier, Oberhauser, & Prügl, 2006; Surry & Ely, 2007; Lynch, 2007; Kalba, 2008; Suriñach, et al., 2009; and NHS, 2011)

Camerani et al. (2010) summarize three different emerging models to understand the diffusion theory. The first group of research in this area looks at the role of information in explaining the diffusion of a new product. An example of this approach is the epidemic model (Griliches, 1957; Mansfield, 1961). In this framework, *"word-of-mouth"* is seen as the means of disseminating the knowledge of new products and, hence, innovative products spread among potential users following the pattern of infectious diseases. In other words, personal contacts between users are the most important factors affecting diffusion.

The second group of the research emphasizes the importance of potential adopters based on individual determinants, hence, taking the assumption that adopters are heterogeneous. Unlike the first approach, which assumes information and personal contact are solely means of gathering information, in the second approach, adopters are assumed to be fully informed about the innovation. In this regards, a probit model is commonly used as the method to identify the decision to adopt (access and use) particular ICT devices. This framework can be found in David (1966, 1969) and Davies (1979) and more recent studies by Forman and Goldfarb (2006), Grazzi and Vergar (2008), and Arduini et al. (2010).

The third group examines the adoption as a decision process influenced by the stock of previous adopters where the effect can be negative. As an example, it can be the case that in 'game theoretic' models, the number of adopters decreases individual profitability in the future (Reinganum, 1981). Conversely, the impact can also be positive, with the stock of previous adopters creating a positive externality. This chain is explained in the form of direct or indirect network effects (Katz and Shapiro, 1985, 1994; Farrel & Saloner, 1985). Direct network externalities can be found in the basic telecommunication services. This arises when infra-marginal consumers connect to a communications system. In this case, a subscriber's utility depends on the size of the subscriber base with compatible access. Indirect network externality also deals with the relation between sectors. Katz and Shapiro (1985) explained that the hardware-software paradigm is a common example of this, with consumers tending to buy hardware, which is mostly purchased with the anticipation that the amount and variety of software are an increasing function of the hardware units being sold.

The last group of diffusion models the process based on the order of adoption. By definition, early adopters are assumed to have first-mover advantage over later adopters (Ireland & Stoneman, 1985; Fudenberg & Tirole, 1985). Late adopters are permeably entitled to two opposing forces. The first is a so-called bandwagon effect, which is triggered by the observation of previous adopters creating such phenomena of fads and fashions. The second is a so-called 'snob effect', which happens as a denial when potential adopters try to look different from others and thus reject the innovation (Abrahamson & Rosenkopf, 1993).

The appended papers in the dissertation (Papers 5, 6 and 8) employ the second group of analysis, which uses mainly the probit model to estimate the demand for access and usage. The following section exemplifies ICT production and diffusion on certain products and services based on previous studies.

Telecommunication

The telecommunication sector has been identified as the driver of economic growth by many previous studies (Cronin, Parker, Colleran & Gold, 1991; Norton, 1992; Madden & Savage, 1998; Dutta, 2001; Nadiri & Nandi, 2011). The important notion of the sector is the existence of the critical mass at which the impact of the sector is highly related to a point that enables further spillover. The study by Roller and Waverman (2001) concluded that the positive impact of telecommunication infrastructure on economic growth is only visible if the critical mass of a 40% penetration rate has been achieved. Thus, the study suggests that the positive impact is only for the OECD countries. Discussing the same aspect, Torero, Chowdhury and Bedi (2002) find different rates of critical mass. By examining a wider sample and time frame, they show that the impact of the network externalities from the telecommunication infrastructure on growth is not linear; the strong relationship is only apparent for the countries whose teledensities are between 5 and 15 % (i.e. high- and low-middle-income countries), hence for the OECD countries, contrary to the previous study, this effect is surprisingly undetectable. The study concludes that the telecommunication infrastructure is believed to enable another industry shift in terms of productivity level. Thus, convergence in the development of telecommunication infrastructure is an important tool in closing the development gap between countries.

Related to this aspect, Antonelli (1991) found that every dollar per capita increase in investment, especially in the telecommunication sector, creates a stronger diffusion effect in countries that are late starters and a weaker effect in countries that start earlier. Similarly to this finding, Berndt and Morisson (1995) combine macro data and industry firm data based on international cross-sectional country data to explain that the return of investment in telecommunication equipment is greater than 30%, making the spillover effect of equipment investment substantial. However, when the data are confined to developed high-productivity countries, the relationship between equipment investment and economic growth disappeared.

Mobile communications

Granstrand (1999) forecasted that the importance of the device can be related to the "human communication" reason. This assumes that people are becoming increasingly electronic and embedded in telecommunication systems that are more interactive, selective, multimedial and asynchronous at the same time. Mobile telephony is now a growing interest, especially in developing countries, due to the fact that most of these countries are enjoying the leap-frogging process. The transition to a greater cellular penetration rate is a low-cost, quick and inexpensive way to increase telecommunication penetration (Sridhar & Sridhar, 2004). However, a later study by Gruber and Koutrompis (2011) found that the contribution of the mobile telecommunication infrastructure to economic growth for low penetration countries is found to be smaller than for high penetration countries, suggesting increasing returns from mobile adoption and use. Other studies in this discussion are Gruber (2005), Aker (2008, 2009), Muto and Yamano (2009), Vogelsang (2009) and Mbogo (2010).

Computers, the Internet and broadband

Computers become important as information processors (Newel & Simon 1976; Galbraith, 1977). The role of computers has been heralded since the invention of the first one, the Mark I, in 1939, and the first electronic computer without moving parts, the Electronic Numerical Integrator and Computer (ENIAC), in 1943. Yet, there is no better quotation to mention than Solow's sarcastic statement about the impact of computers: *"You can see the computer age everywhere but in the productivity statistics*." The paradox shows the discrepancy between measures of investment in information technology and national income accounting.[9] However, recent studies have helped to figure out clearly the positive impact of such devices, especially in reducing the cost of coordination, information processing and communication. The technological progress of the computer contributed roughly 0.3 percentage points per year to real output growth (Jorgensen & Stiroh, 1995; Oliner & Sichel, 1994; Brynjolfsson, 1996). Caselli and Coleman (2001) suggest, based on the report by the

[9] Brynjolfsson (1993) explains that the productivity paradox exists for two reasons: firstly, the results of this spending are applied locally and cannot be expected to show up in aggregate statistics at national level, and, secondly, the benefit from IT investments often requires structuring or major cost cutting, and it is thus possible that firms have yet to undertake reporting this to the government. Nevertheless, the measurement problem also potentially contributes to this issue.

National Bureau of Economic Research (NBER), that the adoption of computers is associated with the higher level of human capital in the OECD countries.

With regard to the Internet, Litan and Rivlin (2001) show that it has created an increase in the level of productivity in the United States economy since the mid-1990s, while the ubiquitous adoption of broadband and the current generation of technologies generate USD 63.6 billion of capital expenditures in the United States economy, according to Crandall, Jackson and Singer (2003). The other studies concluding the importance of broadband can be found in Katz (2009), which suggests that the multiplier of broadband varies between 1.43 and 3.60, and Liebenau et al. (2009) who found that the impact in the United Kingdom created around 280,500 new jobs following a GBP 5 billion investment in broadband deployment. The Strategic Network Group (2003) also estimated that the impact of the investment in fibre optic networks in a small city in Florida can be investigated through the effect of new job creation, expansion of commercial facilities, increased revenue and decreased cost.

2.3. The relationship between the literature review and the appended papers

As has been explored in this section, there are many ways that technology in general and ICT sectors and products, in particular, are capable of stimulating economic development through human capital, investment and productivity. The framework of ICT production and diffusion is also presented to explain how ICT production through output generation and capital accumulation plays an important role in contributing to increasing output. Likewise, ICT diffusion of many products (telephony, computer, Internet and broadband) has been exemplified to show the contribution to output from the diffusion side. Table 2.1 shows the appended papers based on ICT production and the diffusion framework.

Table 2.1 Relationship between the framework of the study and the appended papers

Level of ICT analysis	**Impact of ICT**		**Targeted impact on**
	Production	**Diffusion**	
Product/devices			
Telephony		Paper 10	Quality of life (productivity, household income and participation)
		Paper 9	Socio-economic variables (health and education)
		Paper, 5, 6, 8[10]	
Broadband/Internet		Paper 4	GDP growth
Industry			
IPTV		Paper 11	Output multiplier and GDP
Sub-sector			
Media and content	Paper 3		Output multiplier and GDP
Sector			
ICT sectors	Paper 1 Paper 2		Output multiplier and GDP
Telecommunication	Paper 7		Output multiplier and GDP

[10] The papers identify the demand analysis of cellular (mobile phone) and mobile broadband with no linkage to impact assessment.

From Table 2.1, it can be seen that the appended papers evaluate the ICT sectors in terms of both production and diffusion. Moreover, the papers investigate ICT from different layers based on sector, sub-sector, industry and product. Like many previous studies, ICT production and diffusion are analysed in relation to their impact on GDP.

Of the appended papers, Papers 9 and 10 present different standpoints looking at the relationship between ICT development (telephony) and socio-economic variables. Based on the reason that socio-economic variables (health, education, poverty, etc.) are still problems in developing countries, the appended papers strive to investigate the relationship between ICT and these aspects. Additionally, the investigation is also based on common criticism of the use of GDP as a single indicator reflecting welfare. Early economists and philosophers incorporated the pursuit of happiness in assessing welfare. However, as economists grew more rigorous and quantitative, a more parsimonious definition of welfare took hold; hence, the explanation that QOL is affected only by income is generally challenged (Graham, 2009). GDP, which places greater emphasis on the achievement of material aspects, has received much criticism in the past few decades by, among others, early economists such as Hicks (1940), Kuznets (1941), Galbraith (1958) and Samuelson (1961) and recent ones like Dasgupta and Mäler (2000), Ng (2003) and Kahneman et al. (2004). An assessment of the impact of telecommunication development should therefore also move beyond merely investigating the impact on GDP, as has been found in the majority of the current studies.

Chapter 3 ICT economy across regions

This chapter discusses the relevant empirical studies and previous literature on the impact of ICT sectors in each region. The chapter underlines some identified problems of ICT production and diffusion in each region.

3.1. Introduction

The transformation of the world economy by the revolution in ICT was actually started many years ago, denoted by the invention of the transistor back in the late 1940s (Jalava & Pohjola, 2008). This invention, followed by many others, has brought and contributed to a significant price decline in products and services in the last 50 years. As a result, society at large has witnessed the era of the late 1990s, which was so different from the previous periods, raising the phenomenon of a so-called 'new economy'. Jalava and Pohjola (2008) assert the importance of the ICT sectors stating that, while the contribution of steam to British economic growth in the nineteenth century was only modest and long-delayed (contributing about 0.01-0.02 percentage points to the growth of labour productivity before 1830 and peaking at 0.4 percentage points in the period 1850-70), the impacts are much smaller than the basis of many recent studies measuring the effects of ICT on the growth of the economy. In this regard, four factors have been identified that stimulate the role of ICT: a rapid improvement in quality, a sharp decline in prices, a convergence in communication and computing technologies, and swift growth of network computing (Pohjola, 2002).

Cortes and Navarro (2011) stated that the impact of the ICT sectors on economic growth and development requires a substantial process. Hence, it is only visible in the longer term, especially when countries have been able to use ICT to integrate the world market as a result of globalization. The importance of integration in the diffusion of ICT is also explained by Shih and Chang (2009). Based on the empirical analysis of 48 countries, Shih and Chang (2009) identified four blocks of international technology diffusion: the leading countries provide a source of technological knowledge (e.g. the United States, Germany, China, the Netherland, Sweden); an intermediate group diffuses the knowledge acquired from the source (e.g. Canada, Belgium, Spain, Singapore, Austria); a third group initiates the export of technological knowledge (Ireland, Brazil, Israel, Malaysia, Mexico, the Czech Republic); and a final group of countries absorbs technological knowledge without reciprocal exportation (Greece, Iceland, Indonesia, Lithuania, Malta). The study concluded the need to link to international ICT centres as the spillover effect is a crucial agenda for the less developed countries, as countries in the absorber block do not have any brokerage opportunities because they have no outward linkage. Gong and Keller (2003), for instance, measured that the relative importance of foreign technology in most of the less developed countries is at least 90%, supporting the need for integrating ICT development.

Previous studies also found that the two-way relationship between ICT and economic development also varies considerably between countries. For the factors affecting ICT development, Kiiski and Pohjola (2002) found that in the developed countries (OECD), the GDP per capita and access price influence the growth in ICT penetration (e.g. computers) while competition and education are not such significant factors. On the other hand, an educational level plays a significant role in the case of developing countries. Seo, Lee and Oh (2009) found that countries with solid economic infrastructure and open trade regime experience more active ICT investments. Billon, Lera-Lopez and Marco (2010) also found that in countries with higher levels of ICT adoption, the digitization pattern is explained by GDP, service sector, education and governmental effectiveness. In contrast, in developing countries, population, age and urban population are positively associated with ICT adoption.

On the direction of ICT to economic growth, Dutta (2001) found that the causality pattern of ICT (e.g. telecommunication infrastructure) and economic growth was almost the same for industrialized and developing countries. Another study by Chakraborty and Nandi (2011) shows that the impact of telecommunication infrastructure investment on GDP growth varies even between developing countries inferred from the model employing some control variables. The study is conducted by relating the country-specific data to mainline (fixed) teledensity and per capita growth using the Granger causality test within a panel cointegration framework. The results suggest that growth effects vary considerably across country groupings showing the different levels of development with teledensity and per capita growth strongly reinforcing each other for relatively less developed countries. The study suggested that the investment in telecommunication infrastructure, with its potential to generate a high growth return, may serve as the critical engine for driving the development process in the less developed countries.

For a broader picture of the relationship between ICT and economic growth, Lam and Shiu (2010) summarize the different patterns of this relationship based on previous empirical studies.

Table 3.1 Previous studies on the relationship between telecommunication infrastructure and economic indicators

Authors	**Methodology**	**Data used**	**Results**[11]
Cronin et al. (1991)	Granger causality and modified Sims test	USA, 1958-1988	Telecommunication investment ↔ GDP
Cronin, Gold, Herbert and Lewitzky (1993)	Granger causality and modified Sims test	Pennsylvania, USA, 1965-1981	Telecommunication investment ↔ employment
Cronin et al. (1993)	Granger causality and modified Sims test	USA, 1958-1990	Telecommunication investment → aggregate and sectoral productivity growth
Madden and Savage (1998)	Granger causality	27 Central and Eastern European (CEE) countries, 1990-1995	Telecommunication investment ↔ GDP
Dutta (2001)	Granger causality	15 developing and 15 industrial countries, 1960-1993	Telecommunication investment →per capita GDP
Cieslik and Kaniewska (2004)	Granger causality	Regional panel data, Poland, 1989-1998	Teledensity →Retail sales per worker
Yoo and Kwak (2004)	Granger causality	Korea, 1965-1998	IT investment ↔ GDP
Wolde-Rufael (2007)	Granger causality	USA, 1947-1996	Telecommunication investment ↔ GDP
Lam and Shiu (2010)	Dynamic panel data model	Regional panel data, China, 1978-2004	Overall: GDP → Teledensity High income region:

[11] Unidirectional causalities are denoted by a one-way line direction between two variables, while bi-directional causalities are shown by two-way line directions.

			Teledensity → GDP Other region: no causality or GDP → Teledensity
Ding and Haynes (2006)	Dynamic fixed effect model	The inter-regional study in China, which is conducted over a 17-year period from 1986 to 2002 in 29 regions	Telecommunication infrastructure → GDP growth[12]
Karner and Onyeji (2007)	Panel data	14 African and 13 European countries during 1999-2005	Telecommunication infrastructure ↛ GDP growth
Chakraborty and Nandi (2011)	Granger causality	12 Asian countries, 1975-2000	Degree of privatization: High: Teledensity ↔ GDP Low: Teledensity → GDP

Source: Lam and Shiu (2010) and extended studies collected by the author

Table 3.1 shows that the direction and impact of ICT on the economic indicator (GDP) vary between time series and regions, which means that the assessment of the impact of ICT is country and time dependent. The impact also varies when control variables are assigned (for instance, initial GDP and level of privatization). Nevertheless, in general it can be concluded that there is a positive relationship between ICT development (infrastructure development) and GDP growth.

The regions and countries are also unevenly investigated, in terms of the numbers of studies. Using data from a total of 41 countries and 6 regions between 2001 and 2010, Srinuan and Bohlin (2012) show that most of the studies on ICT development and, particularly, the digital divide were found in the North American region (24.5%), followed by Europe, Asia Pacific and, to a lesser extent, Africa, with 24.0%, 22.6% and 6.7% respectively. Comparative studies by region and country therefore seem important to filling the gap of the current analysis.

The following section explores the ICT economy in Europe, Asia and Africa describing the recent phenomenon in terms of ICT production and diffusion. The production side mainly deals with the structure of ICT manufacturing and services whereas the diffusion and adoption mainly concern the attainment of the penetration rate of ICT devices.

3.2. The European region

The European region has long been planning to become an information society as mandated based on the Lisbon Strategy enacted at the EU Spring Summit of March 2000. The agenda possesses a long process of economic, social and environmental renaissance for the European region with its ultimate goal to achieve the most competitive knowledge economy by the year 2010. In responding to the aim of achieving the target and knowing that the region is at a different economic stage, the European Commission (2003) reported on several case studies in selected countries to familiarize itself with

[12] The magnitude is decreasing, suggesting that in the early stages of development the regions will enjoy the greater impact. The finding supports the convergence hypothesis that regions with a higher level of GDP per capita tend to have a slower rate of growth.

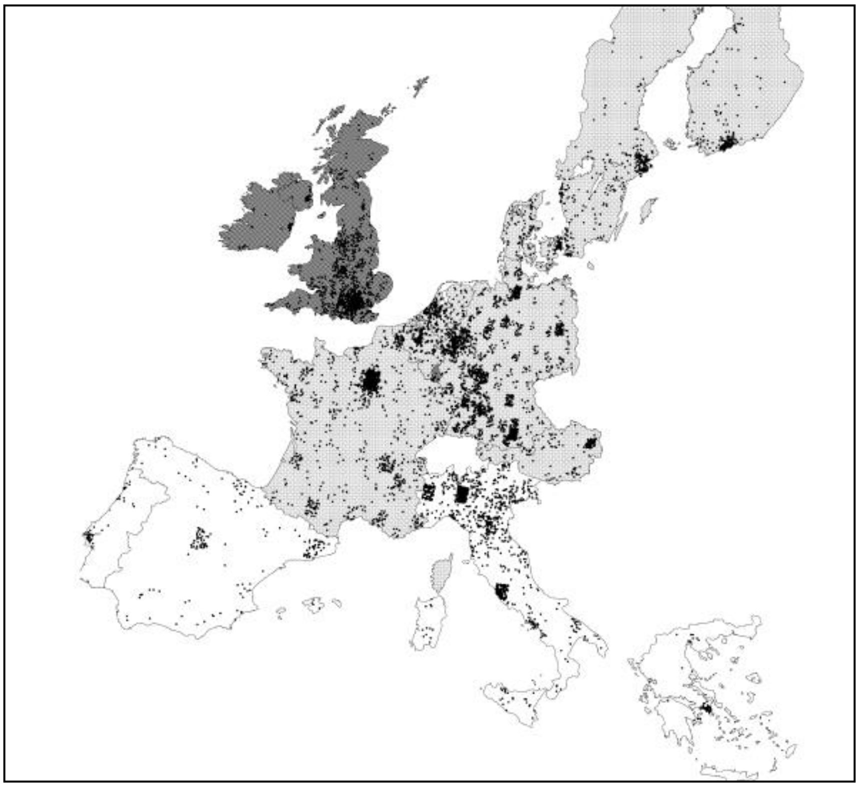
existing potential and threats in an attempt to become an information society. The report divides the countries into two groups: “old tiger” and “new tiger” with their specific problems and obstacles.

Based on the report, Austria is labelled an “old tiger” in the region given the fact that the country was among the fastest-growing European economies from 1950 to 1960 but failed to change the structural platform in the information country despite still being one of the richest countries in Europe. In this regard, Austria’s institutional set-up with its strong corporatist elements and its consensus-orientated policy did well in the times of catching up (1960-1990) but did not achieve as many structural changes as other notable Nordic countries. Like Austria, Belgium is also a so-called “tiger country” in which it is believed that the potential of ICT-related development is stronger than its current actual usage. This means that the society as a whole has not realized the full potential benefit that ICT development can bring. The ICTs are therefore under-exploited. De Vil et al. (2002) mentioned that apart from the fact that the country has the benefit of the sector; Belgium is at the bottom of the league of European countries in terms of ICT manufacturing production. Only 1% of the business sector’s added value comes from this sector, a similar level to that seen in Italy and Portugal.

On the contrary – despite the recent crisis – up to 2002 the Greek economy was considered to be a “new tiger” and among the fastest-growing economies in the EU. This finding was related to the big increase in investment in previous years at times when its achievement was comparable to those of Portugal and Spain. Even the country was characterized by some of the lowest figures in indicators related to the Information Society; it was supposed to be the highest growth economy.

The other group of countries – Ireland, Finland and Sweden – has features in common and its position contrasts with that of the rest of Europe where three countries stand out with very strong ICT manufacturing profiles. ICT manufacturing takes up 40-70% of their ICT workforces. Vicente and Lopez (2006) show that ICT has a positive and significant correlation with the level of GDP per capita and the availability of a skilled workforce measured by the percentage of human resources in science and technology over the total population. Therefore, the results put the Nordic regions entitled to the advantage in ICT over the rest.

In terms of the production side, Koski, Rouvinen and Yla-Anttila (2002) identified two main features of ICT establishment in Europe: (i) ICT has become more concentrated, and (ii) the countries originally specializing in ICT are becoming even more so. The concentration of ICT establishment is spread from the Greater London area through Germany’s industrial heartland and ends in northern Italy and the Scandinavian block that covers the Helsinki and Stockholm metropolitan areas. The first block clusters concentrate more on information technology (IT) and the later on communication technology (CT). The clusters of ICT manufacturing in Europe are shown in Figure 3.1.



Source: Koski, Rouvinen and Yla-Anttila (2002)

Figure 3.1 Clusters of ICT manufacturing in Europe

The figure shows the ICT-related establishments based on the firm and industry survey carried out in 11,000 establishment in the European region (retailers and distributors are excluded). The figures clearly picture the geographical clustering of ICT production in which the author mentioned three European countries – Finland, Ireland and Sweden – currently specializing in ICT production, technology and trade. Finland has recorded a massive structural change considering it was one of the least ICT-specialized countries back in the 1990s. Regarding this, Jalava (2002) explains that the phenomenon in Finland is the impact of a positive reallocation of labour, which was primarily a consequence of an increase in the employment share of ICT production.

Besides the clustering, the convergent exports from the European countries have increased trade of ICT products, intermediate goods and components. De Vil et al. (2002) elaborated that the ICT trade is of great importance to the external balance in the European countries. For instance, in Ireland, the ratio of trade in ICT sectors accounted for 30% of the total trade. A similar phenomenon can be found in Hungary and Finland, where the ICT trade accounts for almost 20% of the total trade. While the establishments are clustered, the activities themselves are borderless within the European region, which implies that policies focusing on national interest will be inadequate and instead more local and/or regional policies will be needed to promote ICT (Koski, Rouvinen & Yla-Anttila, 2002).

Looking at the OECD countries, De Vil et al. (2002) identified that ICT production is ranked into four categories from the most important to the least important and also shows the position of some European countries[13]:

- First rank: the United States, the United Kingdom and two Scandinavian countries (Sweden and Finland)
- Second rank: the other Scandinavian countries (Norway and Denmark) and Anglo-Saxon countries (Canada and Ireland) as well as Austria
- Third rank: the centre of the European Union – Germany, France, Netherlands, Belgium – as well as Italy, Portugal and Japan
- Fourth rank: the south of Europe – Greece and Spain

To define the general problem of the ICT economy in Europe, the United States is commonly used as the base for studies. Jalava and Pohjola (2002) stated that the production and use of ICT were factors behind the improved economic performance of the United States in the 1990s. Yet, the evidence of the "new economy" is much weaker outside the United States. Van Ark, O'Mahony and Timmer (2008) conducted a comparative analysis between the productivity rate in the United States and that in Europe. The study reveals a slowdown in productivity and contribution by the ICT sectors to economic growth in the European countries compared with the United States. The slowdown is also attributable to the slower emergence of the knowledge economy driven by the lower growth contributions from investment in information and communication technology in Europe, the relatively small share of technology-producing industries and slower multifactor productivity growth, which is viewed as a proxy for advances in technology and innovation. Table 3.2 shows the structure of economic growth and the contribution of ICT in the European region.

Table 3.2 Contribution to growth of real output in the market economy (%)

No	Variables	European Union	
		1980-1995	1995-2004
1	Market economy output (2)+(3)	1.8	2.2
2	Hours worked	-0.6	0.7
3	Labour productivity (4) + (5) +(8)	2.4	1.5
	Composition		
4	Labour composition	0.3	0.2
5	Capital services per hour (6) +(7)	1.2	1
6	ICT capital per hour	0.4	0.5
7	Non-ICT capital per hour	0.8	0.5
8	Multi-factor productivity	0.9	0.3
	Contribution of the knowledge economy to labour productivity (4) +(6) +(8)	1.6	1.1

Source: van Ark et al. (2008)

[13] When ICT sectors are defined, particularly, by telecommunication, the size of economies is important showing less specialization and greater importance of local markets. Some countries are identified as having a big market, such as Italy, Portugal and, to a minor extent, Germany and Austria (De Vil et al., 2002).

Table 3.2 reveals that although the European countries enjoyed a slightly higher contribution of ICT capital during the period 1995-2004 than in the previous ten-year period (0.5 compared with 0.4 %), there was a considerable decline in the contribution by the knowledge economy from 1.6 to 1.1 % between the first and the second period[14]. This decline was driven by three factors: labour composition (4), capital deepening (5) and multifactor productivity. Of these factors, multifactor productivity fell from 0.9 to 0.3%. According to van Ark et al. (2008), this finding reflects the overall inefficiency of the production process.

Like this explanation, Barrios and Burgelman (2008) also concluded that the main problem of the ICT sectors' impact on the EU economy (compared with the United States) has been identified as the results of the slower intake of ICT capital. When the investment was made, it was unfortunately also released at a lower rate than that in the United States. The impact of ICT on GDP growth has also been much less pronounced during the past ten years or so. Admittedly, while some EU countries seem able to speed up the investment, these countries are, generally, relatively small so their overall influence on the EU is almost undetectable. The slower rate of investment is also attributable to the market rigidities that deter further impact of ICT investment on economic growth. This aspect concerns business regulation, the labour and credit markets that generally put European countries below the United States (Barrios & Burgelman, 2008).

While the diffusion aspect of the attainment of the ICT penetration rate in terms of basic communication devices (mainly telephony) has generally been high, the divide between countries is still visible, especially when comparing the leading countries in the Northern regions with the Southern and Eastern territories. Based on the analysis, which consists of 164 regions covering the EU-27, Vicente and Lopez (2006) found that the United Kingdom and Greece have the biggest gaps within countries, even though the first-mentioned is in the top ten countries in terms of the highest ICT progress in the region. The study also found insignificant impact of urban density, showing that the digital divide phenomenon in the European region is not merely an urban-rural problem.

The current greatest challenge of the region actually concerns the diffusion of broadband. It is generally understood that broadband access is vital to provide users with high speed, always-on connectivity to the Internet as well as a means for consumers and firms to exploit the great potentials of new applications (Distaso, Lupi & Manenti, 2006) and to achieve better social cohesion (Turk, Blazic & Trkman, 2008). When it is served at a high speed, broadband can also serve as the transition path for the incremental and demand-driven upgrade of local telecommunication access capacity (Cawley, 1997). The European Commission has therefore pushed broadband as the tool of social and economic policies in recent years as it strongly relates to the goal to further the information society and knowledge economy developments (Preston, Kerr & Cawley, 2009).

Although the diffusion rate keeps increasing, not all countries in the European region have the same rate of broadband adoption (Kyriakido, Michalakelis & Sphicopoulos, 2011). Jakopin (2009), and Bauer, Berne and Maitland (2002) show that the broadband divide in Europe is influenced by the

[14]Van Ark, O'Mahony and Timmer (2008) explain that ICT production includes manufacturing of electrical machinery and post and telecommunication services. Goods production includes agriculture, mining, manufacturing (excluding electrical machinery), construction and utilities. Market services include distribution services, and financial and business services, excluding real estate and personal services. The market economy is the sum of three products. The numbers may not total exactly due to rounding.

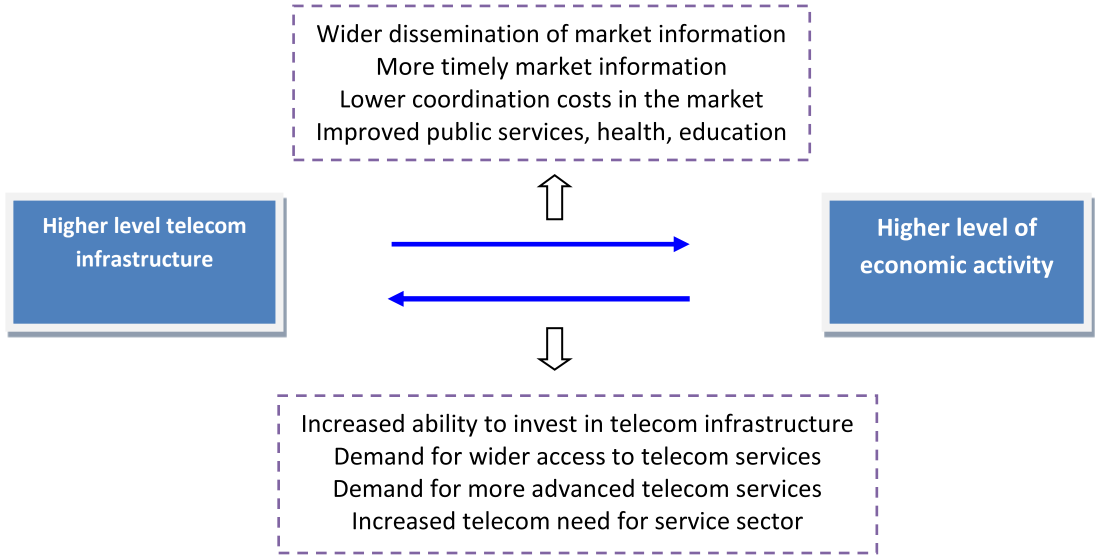
difference in economic prosperity, the level of infrastructure development and computer literacy (to initiate broadband penetration). English language proficiency, which affects the attractiveness of global web content for Internet subscribers, teleworking, which increases the base of potential early broadband adopters, and service sector employment, which positively correlates with the need for information access, also influence the rate of broadband adoption (Vicente & Lopez, 2008).

The slower emergence of broadband diffusion is also addressed from the policy perspective that the EU's legacy of broadband policy to date is seen to be a technology-centred policy frame that privileges supply-side infrastructure and neglects demand-side issues of applications, uses and users (Preston, Kerr & Cawley, 2009). Ironically, Taaffe (2011) pictures this from the private sector standpoint. A slower rate of broadband deployment in, among other places, Europe is driven by the fact that the investor is unsure of the consumer demand. In relation to this, many studies have also found that the demand-side and socio-economic variables play a significant role in the European broadband market (Robertson, Soopramanien & Flides, 2007), namely the subscribers' profile, users' income and willingness to pay (Deligiorgi, Vavoulas, Michalakelis, Varoutas & Sphicopoulos, 2007; Vicente & Lopez, 2008). The later study also puts stronger emphasis on the need to pay more attention to the elderly to close the broadband gap, as well as education and income factors.

On other ICT devices, mobile telephony, the problem concerning the slower diffusion investigated by Weber, Haas and Scuka (2011) concerns the innovation rate. The study concluded that, in the case of cellular devices, the industry in Europe generally lacks innovation, denoted by fewer functions of handset technology compared with other leading countries such as Japan, the United States and Canada. The study shows how the Japanese industry initiated a so-called 'disruptor' on the mobile Internet back in 1999 followed by many other services (camera, flat rate for data, eWallet, GPS, etc.). Canada and the United States followed later as the countries of origin of the Research in Motion (RIM) Blackberry and iPhone Apple. The new services introduced to the market in the European region, however, were seen as conventional as they were introduced based on a conventional MMS platform (Scuka, 2003). The lack of innovation is also amplified by the pricing policy, with the price plan in Europe generally higher than that in Japan for similar services of mobile Internet (Weber, Haas & Scuka, 2011).

3.3. The Asian and African regions

Africa and Asia are the regions inhibited by the majority of developing countries. In these regions, it is believed that ICT development should be able to contribute beyond merely economic growth (measured by GDP) to other socio-economic aspects that relate to quality of life (QOL), for instance, poverty alleviation, education and health (Chakraborty & Nandi, 2011; Dimelis & Papaioannou, 2011) akin to the huge and common problem concerning the gap in income, human skills and lack of infrastructure (Quibria, Ahmed, Tschang & Reyes-Macasaquit, 2003). The framework by Dutta (2001) in Figure 3.2 best suits the goal in developing countries that ICT sectors should play a more important role in the region by providing an efficient market, cost reduction and better socio-economic platforms.



Source: Dutta (2001)

Figure 3.2 Relationship between ICT investment and economic growth

From Figure 3.2, it can be verified that either direction between higher ICT development (e.g. telecommunication infrastructure) and economic activity has positive feedbacks for the other. The impact should also be detected in terms of reducing cost and increasing market efficiency (Dimelis & Papaioannou, 2011) and other socio-economic variables, e.g. education, health and poverty alleviation (Wijers, 2010; Kijsanayotin, Kasitipradith & Pannarunothai, 2010; Crow et al., 2012; Kiiza & Perderson, 2012).

3.3.1. Asia

Asia Pacific is addressed as the region with radical contrasts to some of the countries, even leading the world ICT economy while others are left far behind (Ozawa, 2003; Chin, 2005; Samarajiva & Gamage, 2007; Yu, 2008). Ozawa (2003) stated that the success story of NIEs in East Asia is driven by the flying-geese model of industrial upgrading that has been applied to the emergence of Pax Americana-led growth clustering and the high propensity of the United States to transplant manufacturing overseas in the East Asia region. The model, however, does not appear to have been adopted in other developing countries in Asia.

On the positive side, Kanamori (2004) reveals that communications equipment made a positive impact on all the Asian economies during the 1990s, and the size of the impact was similar in most of the Asian economies. In other words, the results show evidence of rapid investment in communications equipment in these economies and the important role of the communications equipment industry. In India, Umar and Chada (2002) found that the industry has created enormous job opportunities. The software industry, for example, had absorbed 340,000 professionals by 2000, 25% higher than that in 1996. In a highly populated country like India, the creation of jobs is still insignificant, however, as it may not add up to more than half a million including ancillary workers.

The report by Lim and Wi (2001) shows the specialization of ICT production in Asia noting that all NIE countries (together with developing countries notably Malaysia, Thailand, Vietnam and the Philippines) were major manufacturers and exporters in the ICT sectors. The area of specialization shows that Taiwan focuses on notebook PCs, motherboards (79% of the world's products), scanners and casing industries (second only to the United States). Whereas Singapore focuses on hard drives, Korea on memory chips and Hong Kong on semiconductors and ICs

Instead of an evolvement throughout the Asian region, however, recent studies show that ICT production activities are even more clustered. Tseng (2009) identifies that the cluster centres on leading East Asian countries (South Korea, Taiwan, Hong Kong and China), and Singapore and India. The study maps the transfer of knowledge in ICT innovation as limited between these countries (e.g. telecommunication, semiconductors and computers). Different relative innovation strengths are also found in these countries, with Taiwan focusing on semiconductors and electrical engineering, South Korea possessing very similar development in all technological fields of ICT, and Singapore focusing on semiconductors. Moreover, electrical engineering and telecommunications are the main fields of relative innovation strengths in Hong Kong. China focuses on electrical engineering, telecommunications and semiconductors whereas India focuses on telecommunications. There are also high inter-relationships between six countries in ICT, with these countries simultaneously disseminating and accepting knowledge from each other.

It is therefore generally conceived that the impact of ICT was more visible, particularly in the NIEs, namely Singapore, South Korea, Hong Kong and Malaysia, over the period 1990-2007 (Kuppusamy & Santhapparaj, 2005; Kooshki & Ismail, 2011). When investigating the South East Asian countries (and Australia), a study by Kuppusamy, Pahlavani and Saleh (2008) shows that while the impact is visible in Malaysia and Singapore, ICT investment did not contribute significantly to economic growth during the same period in Indonesia, the Philippines and Thailand. These three countries have not yet been able to reap the benefits of ICT, suggesting a need for them to increase their ICT investment in order to achieve sustainable economic growth in the new knowledge-based economy. Even for Malaysia, the process is believed to take longer to process through knowledge accumulation (Ramlan & Ahmed, 2009).

Unlike the production side, which shows rather promising features, Chin (2005) presented the disparity in ICT use and rate of adoption in the Asian region as severely and unevenly distributed. In terms of telephony, by the end of 2002, Taiwan had 169.83 telephone subscribers per 100 inhabitants or about 2 lines for every person**,** Hong Kong had 161.26 fixed lines, Singapore 125.84 lines, Macau 120.01 lines, and Japan and Korea 119.49 and 116.61 lines respectively, whereas on the other side of the divide Myanmar had 0.85 fixed lines for every 100 inhabitants, Papua New Guinea 1.41 lines, Bangladesh 1.56 lines, Solomon Islands 1.71 lines, Nepal 1.78 lines, Laos 2.12 lines, Cambodia 3.01 lines, Pakistan 4.42 lines and Bhutan 4.69 lines. The disparity in terms of cellular and Internet adoption is also visible between countries.

Kumar and Chadha (2002) identified some factors that inhibit the pace of ICT diffusion in Asia). They found that income is not the only important factor but that a lack of skilled manpower for the development of local applications, customization and software in local languages and a lack of adequate infrastructure are also responsible for poor diffusion of technology and, in many countries, the telecommunication networks are deficient and not sufficient for data transfer. Added to this, the region also faces a low level of literacy of the local people (Malekian, Omar & Hanan, 2011), urban rural disparity (Nikam, Ganesh & Tamizhchelvan, 2004; Bowonder & Boddu, 2005; Narayanan, Jain & Bowander, 2005; Gamage & Halpin, 2007; Ramirez, 2007) and demographical factors. For instance, in Central Asia (Kirgizstan), Driesbach, Walton, Kolko and Seidakmatova (2009) found that the diffusion of Internet use was concentrated on 'young people'.

Narrowing down the analysis of ICT in terms of the telecommunication sector, it has been found that Asia has reached a more conducive environment, regardless of the political regime in each country. Ure (2008) summarizes this progress concerning the policy and regulations on licensing, interconnection, tariffs and spectrum allocation. These factors are seen as sub-optimal but feasible to enable further expansion of teledensity. Asian countries have different drivers to achieve such an efficient market in telecommunication, for instance Hong Kong is mainly supported by competition whereas Singapore is led by strong government regulation. The study also stated that countries like Myanmar, Cambodia and Vietnam are currently narrowing the gap by integrating with the rest of the world. Table 3.3 shows the progress of telecommunication development with an institutional background, particularly in the South East Asian countries.

Table 3.3 Development of the ICT and telecommunication sector in South East Asia

No	Country	Development
1.	Brunei	As a small and wealthy country, Brunei has reached quite a decent standard of telecommunication infrastructure while most of the ASEAN countries are still progressing, for instance, 100% digitization was reached back in 1995. The country has also been identified as a strong consumer of telecommunication services thanks to support from the government. Improved regulation, especially in relation to the increase in liberalization in the local market, may be needed to increase development in this sector.
2.	Cambodia	Cambodia is still increasing its efforts to direct the building of a telecommunication infrastructure. Unlike most of the Asian countries, which have reached a substantial penetration rate in the cellular market, Cambodia's penetration rate is lower relatively at 57.65%, with even lower performance for fixed lines (only 40,000 subscribers or a 2.54% penetration rate) by 2010.
3.	Indonesia	With 240 million people, Indonesia is a huge market to develop further. Nevertheless, given the varied geographical area, it is difficult for Indonesia to increase the level of telecommunication infrastructure, especially for fixed lines. The fixed line penetration rate was around 15.83% as of 2010. In contrast, the cellular market recorded a dramatic boost with a growth rate of 91.72%, and hence the number of subscribers reached about 220 million by 2010. Historically, the development of the knowledge-based economy (e.g. telecommunication) was initiated by the liberalization of the telecommunication sector (Indosat) in the early 1990s. The policy was followed by the appointment of a national steering committee for IT competitiveness in 1996 when the World Bank provided a USD 35 m loan for this programme. Indonesia also set up the Indonesian Telematics Coordinating Team (TKTI) in 1997, which consists of the cabinet ministers and the Vice President of the country. This team is responsible for defining the government's policy in the area of telematics. In 2001, the use of computers with application programs in the Indonesian language was implemented. In the same year, the country implemented a

		Five-Year Action Plan for the development of ICT in the country. Under this plan, ICT will play a key role in the education system by enhancing collaboration between the ICT industry and the education institutions. Later, based on the National Middle Term Development Planning (Rencana Pembangunan Jangka Menengah Nasional, RPJMN), Indonesia set the target to achieve 30% broadband connection, 50% Internet penetration and 75% broadband penetration for cities and regional capitals by the end of 2015.
4.	Lao P.D.R.	Lao's economy is still seeking to improve performance in general. The low rate of fixed line teledensity, which is only 2 per 100 inhabitants, initiated the plan from the government to seek additional foreign investment. The cellular market achieved a penetration rate of 64.56% by the end of 2010.
5.	Malaysia	Since the mid-1980s Malaysia has enacted initiatives to develop the country into a knowledge economy. Malaysia developed the Technology Park Malaysia (TPM) in 1988, aimed at assisting the development of local technologies and commercializing R&D findings. Moreover, in 1992 the country established the Malaysian Technology Development Corporation (MTDC) whose main responsibility is to promote local research projects and monitor the capital findings of the country. In 1996, it launched the national IT agenda (NITA), which served as the framework for developing the ICT sectors in the country. The telecommunication sector is battling against a more competitive environment in industry. The past decade has shown positive growth in the sector. The mobile penetration rate surpassed 100% by the end of 2010 (120%). In the meantime, the government has issued a number of WiMAX licences as a catalyst for further growth. Fixed line services, however, were still at a penetration rate of 16.1% by the end of 2010.
7.	The Philippines	The country still faces difficulties developing the telecommunication sector, especially fixed lines. The fixed teledensity was less than 7.27% up to 2010, showing difficulties in lifting the network connection. Nevertheless, it has become a phenomenon in most Asian countries for the cellular industry to record massive development. This had reached 85.67% by 2010.
8.	Singapore	Singapore is one of the most advanced ASEAN countries and has been the leader in terms of the knowledge economy over the past three decades. The ICT policies were initiated in the late 1970s. One of the milestones of ICT development was the Civil Service Computerization (CSS) programme in 1981. The policy was aimed at computerizing government agencies and thus increasing productivity in government agencies. Moreover, the country also created a strategic plan called Infocomm 21 (Information and Communications Technology for the 21st Century) in 1999 to prepare the local ICT sectors to face greater competition from global industries. Following this policy, SingTel (a government-linked telecommunication company) liberalized the asynchronous digital subscriber line (ADSL) in 2000. The Information-Comm Development Authorities (IDA) was also introduced focusing on further opening up the broadband services in Singapore in 2002 (Ang, Zhou & Jiang, 2003). Singapore has built a very competitive telecommunication industry and, at the same time, a high-quality, progressively regulated telecommunication environment. Over 98% of homes have fixed-line telephone connections with a fully digital telephone network. Even though the incumbent Singapore telecommunication operator (SingTel) continues to dominate in absorbing

		the market, new operators are also entering the market. The penetration rate of fixed line and cellular devices is among the highest in the ASEAN region with 39% and 143% respectively by the end of 2010.
9.	Thailand	The telecommunication sector has become a rapid economic growth sector, especially in relation to the role of cellular telecommunication. By 2010, the mobile penetration rate was about 100.81% and 10.14% for cellular devices. In late 2004, the national telecommunication regulator undoubtedly played an important role in accelerating the development of the sector.

Source: South-East Asian Telecom statistics, 2007; Kuppusamy, Pahlavani and Saleh, 2008; ITU database, 2011

3.3.2. Africa

Unlike Europe and Asia – the regions with a potentially strong impact from both ICT production and diffusion – the African region is said to have *thintegration* (thin integration) to the global value chain of the ICT industry. There is therefore still limited impact from production as the region still faces slow emergence of economic progress (ITU, 2009; Aker & Mbiti, 2010). The African region still has a long way to go to become a true knowledge society, with some preconditions remaining under-developed both in terms of human capital and physical infrastructure (Rhodes, 2002; Britz, Lor, Coetzee & Bester, 2006). The main problem with the lack of basic infrastructure availability is visible. For instance, less than 30% of the roads are paved; only 25% of the population has access to electricity and less than 3% teledensity in mainline telephony by 2008.

On the other hand, the recent development of information and communication technology has had enormous positive impacts on society. The impacts are particularly obvious for education, information sharing and marketing of African products and services. By 2005, many government offices had been equipped with websites to enable faster diffusion of information and to promote business opportunities, trade and investment. With the limited budget for education, satellite communication becomes vital as an alternative form of education from the most advanced countries in the world from which the African countries are benefitting. Rudra (2008, p. 27) stated that Ghana and Kenya in Africa (together with India, South Korea, Mexico, Brazil, the Philippines) are among the countries that have begun liberalizing their economies and achieving the benefit of the openness of the country that began in the late of 1970s and early 1980s. The ICT sectors have also contributed to better delivery services, progressive impacts on education and health, better governance (leadership and governance), and political stability and self-actualization (Okpaku, 2006). Rorissa and Demissie (2010) also added that despite the region once being labelled a 'technological desert'; the African countries have made noticeable achievements during the last couple of decades obtaining the benefit of ICT devices for government activities. Currently, many African governments present on the Web, including fully fledged e-Government web portals, albeit in small numbers and a digital divide between North and South.

Among other ICT devices, there has actually been tremendous progress in wireless telephony with cellular subscriptions increasing by 49% annually and the number of subscribers increasing by 49% annually between 2002 and 2007, compared with 17% per year in Europe (ITU, 2008). Mobile telephony has also played an important role in closing the digital gap across the urban-rural and rich-poor divides. On the use of ICT devices for the health sector, Aker and Mbiti (2010) added that in regions where Internet services are not reliable, cellular devices have proven an alternative.

Nevertheless, other studies on African countries show that the emerging use of cellular devices is still mainly for maintaining the social network with a weak link to business activities (Horst & Miller, 2006; Malony, 2007). Hahn and Kibro stated that the majority of Ghanaian cellular traffic is aimed at maintaining family relationships. Adoption aims to maintain livelihoods, with the importance of the extended family given the spread of poverty (Rettie, 2008). Diga (2007) reported that based on the survey of the use of cellular devices, the use of the gadget is even substituting household expenditure on food while Samuel et al. (2005) reported that the expenditure on cellular devices reached 15% of the total. Consequently, Donner (2005) found no causal effect between adoption and family prosperity in most of the African countries and more visibly in Burkina Faso by Hahn and Kibora (2008).

Ironically, these findings contradict the phenomenon at the early stage of adoption of telecommunication in Africa, especially of fixed line and public phone coin lines. A survey in Kenya in 1980 and a similar survey in Ethiopia in 1982 showed that most of the use by telephone subscribers was for business purposes. This finding is coherent with another survey on coin box telephone users asking about their motives. It was found that placing and receiving orders, giving and receiving information and administrative work are among the most important reasons for such decisions (Saunders, Warford & Wellenius, 1983). A further investigation into measuring the impact of ICT diffusion on socio-economic variables is therefore an important agenda.

Table 3.4 summarizes the progress of ICT development, particularly in the telecommunication sector, in the African region mainly based on Gordon and Gordon (2007).

Table 3.4 Development of the telecommunication sector in Africa

Period/Year	Country	Findings
Early 1990	Most African countries	Only six countries have cellular devices
1995	Most African countries	Only four countries have access to the Internet
1999	Most African countries	50 countries have access to the Internet
2000	Mali Niger Congo	One phone line per 1000 inhabitants
2000	Most African countries	42 countries have cellular devices
	Botswana	Has built 100% digital mainline whereas the average African countries have 69% and the world average is 79% indicating the leapfrog of developmental status in the telecommunication sector
	Most African countries	The diffusion of Internet was not limited to capital cities but included Internet kiosks, cyber cafes, and public access points, such as hotels and business centres
	Most African countries	24 African universities are linked to overseas classrooms and libraries via satellite
2001	Most African countries	The Imfundo[15] project was initiated to link the citizen and government officers through computer and Internet literacy programmes

[15] The terminology is derived from the Nguni languages of southern Africa. It means "The acquisition of knowledge and the process of becoming educated".

2002	Most African countries	The number of countries with cellular devices reaches 48. Only 1.5 million Africans have access to the Internet, 66% of those users are in South Africa compared with 25% of Europeans and North Americans.[16]
2004	Most African countries	There are now 60 million cellular devices versus 27 million fixed line phones. On access vs. usage, only 2.8% of the population have regular activities on cellular devices but 6% use the cell phone. Access may be higher than the indicated numbers since in major or secondary cities, access is relatively widely available for public phone shops, telecentres and/or sharing of phones
2004	Zambia	There were 50,000 Internet users and this rose to about 168,000 in 2006; though the achievement remains low considering the population is 11 million. A cellular increase of 100% in 2005 reaching 940,000 compared with only 91,000 fixed lines. 2% of male-headed households have a fixed line compared with 1% of female-headed households from the national survey. The other ratio is 5%:3% for cellular phones and 1% male headed on computer. The rural area is the most deprived in terms of infrastructure need with 65% of the population, more than half of whom are female.
2005	Most African countries	The study indicated that the demand for personal communication and business use becomes more obvious.
2005	South Africa Ghana Senegal Kenya Morocco Madagascar	An offshore outsourcing market for telecentres has been developed in South Africa, Ghana, Senegal, Kenya, Morocco and Madagascar though it only created 54,000 jobs. All the African countries are starting to break the dominance of India and the Philippines in this industry.
2006	Most African countries	23 million Internet users in Africa (2.5% of the total population).Though only five countries obtained more than 5% penetration rate in Sub-Sahara: Cape Verde, Mauritius, Seychelles, South Africa and Zimbabwe.

Source: Summarized from Gordon and Gordon (2007) and ITU databases.

The important message from Table 3.4 is that it is difficult to define Africa in a single unit analysis because of the diverging characteristics of each country with some countries having achieved a decent level of telecommunication development while other are far behind.

3.4. The framework and derivation of sub-research questions

Based on previous studies discussing the role of ICT in a theory and empirical investigation (Chapters 2 and 3), this section presents the framework of the analysis of production and diffusion of ICT. The

[16] Jensen (2000) identified that those Internet users are mainly white Africans who have access and are associated with NGOs, universities and private companies.

framework emphasis is on explaining channels in which ICT is linked to economic growth through the production and diffusion side as shown in Figure 3.3.

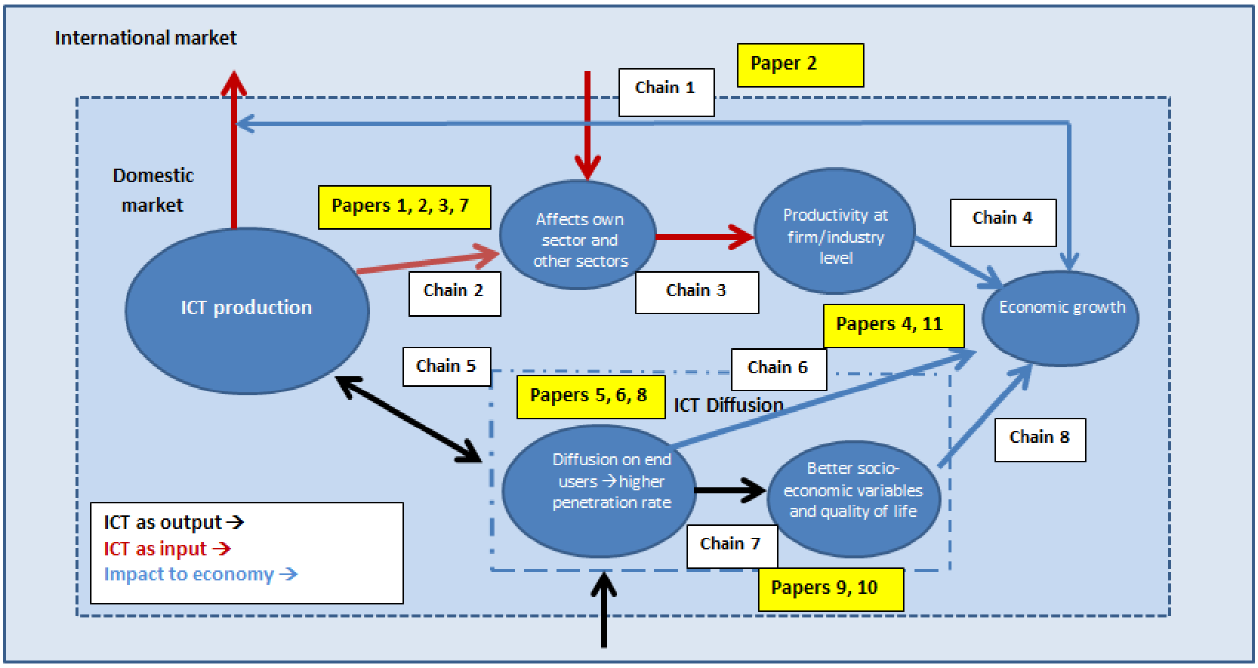


Figure 3.3 Framework of ICT production and diffusion

Figure 3.3 draws two blocks for analysis: the production side deals with the manufacturing of the ICT sectors whereas ICT diffusion explains the diffusion of end-users denoted by an attempt to increase the penetration rate from access and use. From Figure 3.2, it can be explained that:

Chain (1) shows the importance of ICT to the economy from trade activities aimed at producing exportable goods. The output generated from exports adds up directly in the national accounts. De Vil et al. (2002) explained that ICT trade is of great importance to the external balance in some European countries whereas Lim and Wi (2001), and Tseng (2009) show that the specialization of ICT production exports has contributed and is significant among NIE countries in Asia. Moreover, the relationship between trade activities and ICT investment is not one way, Hwan and Young (2009) found that countries with a solid economic infrastructure and open trade regime experience more active ICT investments. Thus, while ICT exports contributed to the economy, opening the market through trading activities also leads to further ICT investment. In this view, pervasive uses of ICT serve as a catalyst for trading activities by creating cost-efficiency in regional trade integration (Epifani & Gancia, 2007) where the ubiquity of ICT also contributes to enlarging global trade expansion and linking nations to the transnational exchange (Dicken, 1998; Cohen et al., 2000). In this chain, **Paper 2** discusses the decreasing export effect in the European region.

Chains (2) and **(3)** explain the importance of the technology and ICT sectors, in particular as general purpose technology, and are thus capable of affecting productivity in the ICT sectors themselves and other sectors. In this regard, the OECD (2009) had seen ICT sectors enable creative destruction through the birth of new firms and greater productivity and economic growth in other sectors. The link is also supported by the increasingly important role of technology and ICT in driving human capital, innovation and productivity (Romer, 1990; Barro, 1991; Gould & Ruffin, 1993; Bresnahan &

Trajtenberg, 1995; Steindel & Stiroh, 2001; OECD, 2009). In Africa, where ICT is still generally thinly integrated into the global value chain, ICT has been found to reduce transaction costs and increase efficiency and market access for SMEs (Stork & Esselaar, 2006). In this chain, **Papers 1, 2, 3** and **7** investigate how ICT sectors affect other sectors in the economy in terms of the multiplier effect. **Paper 3** employs a simulation analysis on how price reduction improves linkage between the ICT sectors and the rest of the sectors.

Chain (4) shows the relationship between productivity at firm level and economic growth. The structure of ICT industries is associated with greater skills and education as well as the creation of efficiency, cost savings and better quality from meso analysis at firm and industry level (Brynjolfsson & Hitt, 1996; Chacko & Mitchell, 1998; Bresnahan, Brynjolfsson & Hitt, 2000). At this stage, there is not yet an appended paper to support this analysis.

Chain (5) links directly to ICT production and diffusion. In view of this, Marcelle (2000) mentioned that it is generally the case that the impact of the diffusion of ICTs is more favourable in countries that also host the global ICT production networks with which the countries are also able to create wealth and produce value from service sector activities or ICT-intensive manufacturing. Even though Wong (2002) found that in Asia this relationship is not always the case. The region faces a huge disparity in ICT diffusion that could be even more severe in the future. The general idea of the dissertation summarizing the appended papers is to try to link this chain.

Chain (6) explains the relationship between the diffusion of ICT products and services and economic growth. This chain can be addressed from the relationship between penetration rates of ICT devices and GDP growth. Such relationships can be found, for instance, in cellular penetration (Sridhar & Sridhar, 2004; Lee, Levendis & Guiterez, 2009), broadband (among others, Crandall et al., 2003; Katz et al., 2009; Atkinson, Castro & Ezell, 2009; Libenau et al., 2009) and telecommunication investment in general (Cronin et al., 1991; Madden & Savage, 1998; Dutta, 2001; Lam & Shiu, 2010; Chakraborty & Nandi, 2011). In this chain, **Paper 4** aims to investigate the impact of broadband upgrading economic growth while **Paper 11** forecasts the impact of IPTV deployment on the economy.

While **Chain** (6) is commonly used to investigate the impact of diffusion of ICT sectors on economic growth, **Chains (7)** and **(8)** are part of the novelty of this study. The need to observe QOL as an alternative has been discussed based on previous studies, as the use of a single indicator, namely GDP, to represent welfare has been challenged (Sen, 1985; Diener & Lucas, 1999; Easterlin, 2003). The link between the impacts of ICT should also consider this alternative standpoint. The relationship between quality of life and economic growth through productivity can be seen in Dalgaard, Schultz and Sørensen (2009); Dabirian, Resvanfar and Asadi (2010); Kingpadung and Phusavat (2010). Investigating the performance of new workers in the United States, Shapiro (2005) found that while the majority of the employment growth effect of college graduates operates through changes in productivity, roughly one-third of the effect seems to come from more rapid improvement in QOL. **Papers 9** and **10** investigate the relationship between ICT development and socio-economic variables and quality of life in Asia and Africa. In addition, **Papers 5, 6, and 8** are not located in any of above chains but are investigated to see the diffusion of ICT devices.

Table 3.5 summarizes the characteristics of ICT development based on the elaboration on each region and scrutinizes the potential problems faced in each region. The sub-research questions are then developed to expand the analysis in each region from the production and diffusion sides. The expansion of the research questions is also linked to the appended papers on which the questions are based. Some questions aim to focus the current problem found in the literature review while others are devoted to strategies and policies to minimize the problem.

Table 3.5 Current problems of ICT production and diffusion and sub-research questions

Region	Problem	Research questions	Appended Paper
Europe	**On production** The ICT sectors contributed little to the overall economy and productivity level, especially compared with the United States (Temple 2002; Jalava & Pohjola, 2002; Barrios & Burgelman, 2008; van Ark et al., 2008; Venturini, 2009).	How can the declining contribution of the output of the ICT sectors in the European countries' economy in the 1995-2005 period be addressed and what particular problems does the European region face concerning the slowdown of the impact?	Papers 1 and 2
		How can the continual price reductions in ICT increase the inter-relatedness between the ICT sectors and the rest of the economy?	Paper 3
	On diffusion The demand analysis and demand side policy are generally left behind in the consideration (Preston, Kerr & Cawley, 2009; Taaffe, 2011).	As demand analysis is generally left behind in understanding the diffusion of technology; what is the future of new services in ICT devices?	Papers 5 and 6
	The ICT industries (e.g. cellular devices) are less innovative in creating new services for the users (Scuka, 2003; Weber et al., 2011).	Will innovative products contribute more to the European economy?	Paper 11
	The digital divide between countries exists especially on broadband (Bauer et al., 2002; Vicente & Lopez, 2006; Jakopin, 2009).	What can be expected from upgrading the broadband speed in the European region based on studies that the European region is still facing the broadband gap?	Paper 4
Asia	**On production** In some developing countries in Asia, the ICT investment contributes little to the economy in which the centre of activities is limited and clustered (Lim & Wi, 2001; Kuppusamy et al., 2008; Tseng, 2009).	What might be the problem as some countries are still unable to benefit from ICT investment in Asia?	Paper 7

	On diffusion The region is still facing a huge digital divide due to geographic dispersion and socio-demographic factors (income, education, etc.) (Nikam, Ganesh & Tamizhchelvan, 2004; Bowonder & Boddu, 2005; Malekian, et al., 2011).	If the policy is to be chosen between the demand side and the supply side (e.g. lack of infrastructure development and income level), which one should be considered first to support the immediate adoption of ICT devices?	Paper 8
	There is no connection between ICT production and diffusion (Wong, 2002).	Have the adoptions of ICT devices in Asia led to better socio-economic variables, in particular health and education?	Paper 9
Africa	**On production**[17] *Thintegration* (thin integration) in the global value chain of the ICT industry (ITU, 2009; Aker & Mbiti, 2010).		
	On diffusion The region still faces a huge digital divide in which the use of current devices is mainly unrelated to economic activities (Rhodes, 2002; Donner, 2005; Britz et al., 2006; Hahn & Kibora, 2008).	Has the adoption of ICT devices (cellular and the Internet) in Africa led to a better quality of life?	Paper 10

[17] In the current state, the dissertation and the appended paper do not address the ICT production (or manufacturing or investment) in the African region claiming that the region has little integration into the global value chain and the ongoing issue still touches on the digital divide/diffusion side. Other studies, explain the emergence of ICT production in Africa (Chowdhury, 2006; Kabanda, 2008; Bollou & Ngwenyama, 2008; Bell & Juma, 2008). A current report by Davies (2010) shows how the emergence of ICT manufacturing is driven by China's manufacturing expansion.

Chapter 4 Methodology and data

This chapter aims to describe the methodologies employed in each appended paper. In summary, there are two main quantitative methods as tools of the analysis: the input-output (IO) and the econometric analysis. The use of the IO model is elaborated on in terms of the multiplier and decomposition analysis, the causative matrix for structural changes and price elasticity, whereas, the econometric analysis employed in this study consists of binomial probit and logit, panel data and the panel cointegration model. The overarching methodology is first explained on the basis of meta-theoretical rationale, which expresses the researcher's standpoint on the research problem.

4.1. Meta-theoretical rationale

The meta-theoretical rationale is concerned with the fundamental challenge faced by any form of research, namely to adopt an approach that will provide insights into the phenomenon or process of interest (Karlsson, 2008, p. 63). Thus, the meta-theoretical rationale explains how the overall research is conducted in relation to the epistemology, ontology and methodology employed. The meta-theoretical rationale implemented in the study is the following:

Table 4.1 Meta-theoretical rationale for research

Concepts	Detail
Ontological orientation	Positivism
Epistemological orientation	Objectivism
Research strategy	Quantitative (Input-output and econometric analysis)
Methodology	Deductive

With regard to Table 4.1, Guba and Lincoln (1994, p.108) explain that the ontology describes the position of social entities in the domain of analysis or, in other words, the theory about the general properties of the reality and the object of study. Thus, the study is categorized as 'positivism' (Bryman & Bell, 2007, pp. 22-23) in the sense that there is a clear separation between the role of ICT sectors and the contribution to the economy and the social actors (people in the domain of the study). The exception is in Paper 10, when the descriptive analysis on the impact of access on cellular devices and the Internet in the African region is investigated and supported by most of the social and cultural arguments. Thus, in this regard, the ontological orientation is 'constructivism' in which realities are local and specifically constructed to show the importance of context.

The epistemology refers to the question of what is regarded as acceptable knowledge in the discipline (Bryman & Bell, 2007, p. 16) that also possesses the nature of the relationship between the investigator and the object of the study (Guba & Lincoln, 1994, p. 108). The epistemological approach in this study is 'objectivist dualism'. This means that the investigator and investigated objects are assumed to be independent entities, meaning that the investigator is assumed capable of studying the objects without influencing them. To do so, the study collects all the information through the document study and other relevant sources and databases and then conducts an investigation and measurement by implementing some assumptions without intervening and influencing the method and data. The methodology concerns how the inquirer can go about finding the results of the study (Guba & Lincoln, 1994). This study uses the deductive method, which means that there are a number of pre-determined hypotheses and assumptions based on theory.

The dissertation can also be said to consist of multiple case studies as it is developed to investigate the existence of impact of ICT on the economy and it presents specific cases in each chosen region based on uniqueness and distinctive background (Yin, 2003). *A case study* is a history of past or current phenomena drawn from multiple sources of evidence that include data from direct observation and systematic interviewing as well as from public and private archives. In fact, any fact relevant to a stream of events describing the phenomenon is a potential datum in a case study because of the importance of the context (Leonard-Barton, 1990; Karlsson, 2008).

Multiple case studies, in which, in this context, production and diffusion are compared between countries, have advantages in relation to the generalizability of the conclusions, models and theory developed. This also avoids the risk related to misjudgement and exaggeration based on limited cases. The method enables mitigation between events when the data and phenomena are compared across cases on the price, which usually has a more limited depth of study in each case. The case should be able to produce similar results (a literal replication) or contrary results but for predictable reasons (a theoretical replication) (Karlsson, 2008). Thus, this dissertation investigates different regions with strong presumptions that each one is unique and that the comparison might yield similar or contrary results.

4.2. Methodology

4.2.1. The IO analysis (Papers 1, 2, 3, 6 and 11)

The input-output (IO) analysis is a theoretical framework and an applied tool that was first constructed by Wassily Leontief in 1936. The first publication of the table presented the interdependence between sectors in the American economy between 1919 and 1929. Since then, the table has been published for over 90 countries. For this seminal finding, Leontief was awarded the 1973 Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel, yet, the origins of IO date back to Francois Quesnay's Tableu Economique, a descriptive analysis that examines the relationship between sales and purchases between different producers and consumers in an economy. This analysis assumes that inputs used in producing products are related to industry output by a linear and fixed coefficient of a production function.

The IO analysis in this study enables investigation at sector level, which has a direct link to firm level as well as macro level. A brief introduction to the method is given in Table 4.2.

Table 4.2 The input-output table

Intermediate transaction Intermediate demand/inputs I	Final demand II	Total output
Primary input Value added III		
Total inputs		

In Table 4.2., the IO table depicts the transaction flow across sectors, with each sector producing a certain output and, at the same time, consuming input from another sector. The table consists of three main quadrants. The first quadrant describes the inter-linkage between sectors in what is known as an intermediate transaction, while quadrants II and III are the final demand and primary input, respectively. Since the sectors are producing and consuming a particular output from other sectors at the same time, the intermediate transaction in quadrant I indicates the intermediate demand that reflects the flow of intermediate output and intermediate input showing the interrelatedness between sectors.

The transaction flow in the IO table can be explained in system equation (4.1) below. Suppose we have four sectors in the economy:

$$\boldsymbol{x_{11} + x_{12} + x_{13} + x_{14} + C_1 = x_1} \quad (4.1.)$$

$$\boldsymbol{x_{21} + x_{22} + x_{23} + x_{24} + C_2 = x_2}$$

$$\boldsymbol{x_{31} + x_{32} + x_{33} + x_{34} + C_3 = x_3}$$

$$\boldsymbol{x_{41} + x_{42} + x_{43} + x_{44} + C_4 = x_4}$$

From equation 4.1, $\boldsymbol{x_{ij}}$ denotes the output from sector i, which is used by sector j as an intermediate input (or in other words, it reflects the input from sector i, which is used for a further production process in sector j). In the IO quadrant, these values are located in quadrant 1. Moreover, $\boldsymbol{C_i}$ refers to the total final demand of sector i whereas $\boldsymbol{x_i}$ refers to the total output of sector i. $\boldsymbol{C_i}$ is put in quadrant 2.

Introducing the matrix notation, we can modify equation (4.1) to obtain the following matrix column:

$$\boldsymbol{x} = \begin{pmatrix} \boldsymbol{x_1} \\ \vdots \\ \boldsymbol{x_4} \end{pmatrix} ; \boldsymbol{c} = \begin{pmatrix} \boldsymbol{c_1} \\ \vdots \\ \boldsymbol{c_4} \end{pmatrix} \quad (4.2)$$

Equation (4.2) consists of two matrices that show the other representation of total output and total final demand. Thus, from (4.2) x denotes the column matrix of output and c is the column matrix of the final demand. The matrices I and A are the identity matrix and technology matrix respectively

$$\boldsymbol{I} = \begin{pmatrix} \mathbf{1} & \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{1} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{1} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{1} \end{pmatrix};\ \boldsymbol{A} = \begin{bmatrix} \boldsymbol{a_{11}} & \cdots & \boldsymbol{a_{14}} \\ \vdots & \ddots & \vdots \\ \boldsymbol{a_{41}} & \cdots & \boldsymbol{a_{44}} \end{bmatrix} \tag{4.3}$$

The left-hand side of (4.3) is the identity matrix: a diagonal matrix whose off-diagonals are zero. Furthermore, A is the technology matrix, which consists of the ratio of intermediate demand to total output, $\frac{X_{ij}}{X}$. Hence, $\boldsymbol{a_{14}}$, for instance, explains the ratio of output from sector 1, which is further used to produce the output by sector 4.

Combining (4.1), (4.2) and (4.3), the equilibrium of the equation for demand and supply in (4.1) can be modified as follows:

$$\boldsymbol{Ax} + \boldsymbol{c} = \boldsymbol{x} \tag{4.4}$$

where the output is denoted as:

$$\boldsymbol{x} = (\boldsymbol{I} - \boldsymbol{A})^{-1}\boldsymbol{c} \tag{4.5}$$

A simple multiplier measures the impact of both the direct and indirect impact, thus the matrix $(\boldsymbol{I} - \boldsymbol{A})^{-1}$ consists of all the sectors in the economy, making household exogenous (Miller & Blair, 1999, p. 245). From the above eq. (4.5), x denotes the output, c is the final demand (C, I, G, X) and $(\boldsymbol{I} - \boldsymbol{A})^{-1}$ is the inverse Leontief matrix where the multiplier coefficient is derived from.

Decomposition analysis (Papers 2, 3 and 6)

It has been ascertained that any change in the economic output between two periods of time can be decomposed, part by part, from the elements built into the output calculation. The method enables us to trace the change of output from the domestic final demand, export effect, import substitution and technology coefficient effect. Roy et al. (2002) define the composition factor as follows:

1. The domestic final demand occurs when the increased economic output is devoted to fulfilling the needs of the domestic market.
2. The import substitution effect is calculated from the changes arising in the ratio of imports to total demand. This implicitly assumes that the imports are perfect substitutes for domestic goods, since the source of supply constitutes an integral part of the economic structure.
3. The export effect occurs when the growth of output is driven by export-oriented demand (foreign demand).
4. The technological effect represents the widening and deepening of the inter-industry relationship over time brought about by the changes in production technology, as well as by substitution among various inputs.

The formula for identifying these decomposition factors is presented in Table 4.3.

Table 4.3 Decomposition of the change in economic output

Factor	Equation
Change in ICT output	$\hat{z}(x_1 - x_0) = \hat{z}[R_1(\hat{u}_1 d_1 + e_1) - R_0(\hat{u}_0 d_0 + e_0)]$
Domestic final demand effect	$\hat{z}R_1\hat{u}_1(d_1 - d_0)$
Export effect	$\hat{z}R_1(e_1 - e_0)$
Import substitution effect	$\hat{z}R_1(\hat{u}_1 - \hat{u}_0)(d_0 + w_0)$
Technology coefficient effect	$\hat{z}R_1\hat{u}_1(A_1 - A_0)x_0$

From Table 4.3, x_{i} denotes the total output in the economy at time i, d_{i} denotes domestic final demand, while w_{i} and e_{i} are the total intermediate demand and total export respectively. Next, u_{i} is the domestic supply ratio defined by $(xi - ei)/di + wi)$, which has the off-diagonal equal to zero. Moreover, A_{i} is the technology matrix and R is $(\boldsymbol{I} - \boldsymbol{\hat{u}A})^{-\mathbf{1}}$.

To explain this analysis more clearly, Figure 4.1 shows how the decomposition analysis is operated and the outputs of the analysis.

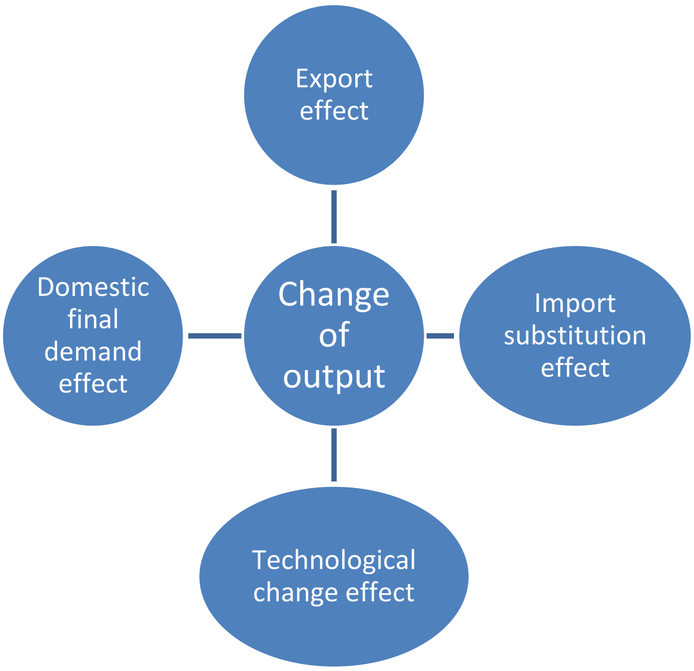


Figure 4.1 Decomposition analysis

Many studies have employed this methodology to answer the research problems concerning international trade, carbon emissions and energy. Some recent studies can be found in Yamakawa and Peters (2011); Zhang and Qi (2011); Butnar and Llop (2007, 2011) on gas emissions; Pei, Dietzenbacher, Oosterhaven and Yang (2012); and Zhang (2012) on trade. On ICT and technology in general, the method was adopted by Cleveland and Ruth (1998), and Wolff (2006).

Structural change and the causative matrix[18]

The causative matrix method aims to identify the connectivity of ICT sectors to the rest of economy. In the context of the IO table, the two sequences of stochastic matrices l are represented by the Inverse Leontief from the IO table. The time dynamic equation of l can be presented in the following eq. (4.6):

$$\boldsymbol{l_{ij}^{t+1}} = \boldsymbol{c_{i1}l_{1j}} + \boldsymbol{c_{i2}l_{2j}} + \boldsymbol{c_{i3}l_{3j}} + \ldots . + \boldsymbol{c_{in}l_{nj}} \qquad (4.6)$$

From eq. (4.6), de Mesnard (2000a) explains that in this context, c is defined as a left causative matrix explaining the change between $\boldsymbol{l_1}$and $\boldsymbol{l_2}$, for instance, during the period $t = 1$ and $t = 2$. As matrix c is completely filled by the $n\ x\ n$ dimension, the matrix is then compared with the identity matrix (I). Hence, to infer the results, all diagonal elements are compared with 1 while all off-diagonal elements are compared with 0. Roy, Das and Chakraborty (2002) classify the results of the causative matrices in the following inference in Table 4.4:

Table 4.4 Inference of causative matrix

	Definition	Off-diagonal elements: $\sum_{k\neq 1} \boldsymbol{c_{ik}} < \boldsymbol{0.0}$ Decreased output impacts generated by other sectors' final demand	Off-diagonal elements: $\sum_{k\neq 1} \boldsymbol{c_{ik}} > \boldsymbol{0.0}$ Increased output impacts generated by other sectors' final demand
Diagonal elements	$\boldsymbol{c_{ii}} > \boldsymbol{1,0}$ Increased relative endogenization of the impact from sector i compared with the rest of the sectors		
	$\boldsymbol{c_{ii}} < \boldsymbol{1,0}$ Decreased relative endogenization of the impact from sector i compared with the rest of the sectors		

The other studies that employed this methodology can be found in Jackson, Rogerson, Plane and O'hUallachain (1990), and De Mesnard (2000b, 2004).

The impact of price (Paper 3)

One of the analyses in this thesis discussed the impact of price changes on equilibrium using the IO framework when discussing the media and content industry in the European region. This analysis is conducted based on the assumptions that all transactions are carried out in a competitive

[18] This part of the analysis does not appear on any appended paper but was part of a licentiate thesis. Rohman, I.K. (2010). *On the ICT economy in the European countries: Investigating the contribution of the ICT sectors using the input – output model* [Licentiate thesis]. Department of Technology Management and Economics, Chalmers University of Technology, Sweden.

environment. By definition, firms maximize their profits subject to a given technological constraint, factor endowments and relative input prices. Heng and Tangavelu (2006) investigate the impact of the information economy on the Singaporean economy. The rationale underlying the model is explained in the following equation:

$$GDP = Gross\ Output - Intermediate\ Inputs - Primary\ Inputs \quad (4.7)$$
$$GDP = P_y\, Y = P_Q\, Q - P_N\, N - P_Z\, Z - P_F F$$

where Y denotes the quantity of GDP real, P_y is the price of Y, Q denotes the quantity of the output, P_Q is the price of the output, N denotes the quantity of the media and content product, P_N is the price of the media and content products, Z denotes the quantity of non-media and content product, P_Z is the price of the media and content products, F denotes the primary inputs and P_F is the price of the primary inputs.

Following Kohli (1978), it can be derived that the GDP calculation is an optimization of a maximization problem.

$$GDP\ (P_Q, P_N, P_Z, F) = max_{Q,J,Z}\ \{P_Q\, Q - P_N\, N - P_Z\, Z - P_F F\ : f(N, Z, F) \geq Q\} \quad (4.8)$$

Then, from equation (4.8), it can be inferred that GDP is a function of the price of the inputs, output and factor endowments. Applying the duality theory, the measurement of profit maximizes the demand for media, and the content products can be obtained by the following Sheppard Lemma in equation (4.9):

$$\delta \frac{GDP}{\delta P_N} = N(P_Q\,, P_Z\,, P_N\,, F) \quad (4.9)$$

Multiplying both sides by $P_N\ /GDP$, the following formula can be derived:

$$\delta \frac{GDP}{\delta P_N} P_N\ /GDP = NP_N\ /GDP \quad (4.10)$$

The left-hand side of equation (4.10) reflects the price elasticity of the media and content sectors on GDP, which can be calculated as the ratio of the value of the input to the GDP. In other words, $NP_N\ /GDP$ will identify $x\%$ change in the GDP as the result of the change in the price of media and content products.

4.2.2. Econometrics model

Panel data (Paper 4)

The panel data are a combination of the time series and cross-section data. The method has some advantages, especially to control individual heterogeneity and present the more informative data that are unobserved in the cross-section econometric testing. The structure of panel data can be presented as follows:

$$Y_{it}\ = X_{it}\, \beta + Z_i\, \alpha + \varepsilon_{it} \quad (4.11)$$

Y_{it} is the dependent variables with a matrix size of $(NT\ x\ i)$, X_{it} is k-regressors of exogenous variables not including the constant $(NT\ x\ k)$, β is the parameter $(k\ x\ 1)$, $Z_i\ \alpha$ is heterogeneity or individual effect, which also consists of a constant, ε_{it} is the error term, i is the cross-section member (individual) and t is time.

Panel cointegration[19] *(Paper 9)*

The term cointegration explains the long-term equilibria between two non-stationary series (Hendry & Joselius, 2000a, 2000b). Based on Granger (1969), Banerjee, Dolado, Gilbraith and Hendry (1993), it is stated that the cointegration techniques ensure that convergence between the two non-stationary series occurs whenever they depart therefrom. To operationalize this techniques, assume there are two non-stationary series that are integrated once $(I[0])$; the series could be back to stationary by linear transformation of differencing in such a way that $x_t - x_{t-1} = \Delta x_t$. In the data generation process with a simple random walk with normalized distribution (thus having mean zero and constant variance), the relationship is as shown below:

$$x_t = x_{t-1} + \varepsilon_t \text{ where } \varepsilon_t \sim N(0, \sigma_\varepsilon^2) \tag{4.12}$$

Subtracting x_{t-1} from both sides yields $\Delta x_t \sim N(0, \sigma_\varepsilon^2)$, which is a stationary series.

Moreover, panel cointegration deals with a similar case to cointegration techniques but on panel databases (a combination of cross-section and time series), whereas the conventional cointegration is commonly used in long-time series data. There are reasons panel cointegration becomes important to the analysis, as Eberhardt (2009) suggested:

- Cointegration provides desirable properties: parameter estimates obtained from a cointegration regression are consistent with a rate of convergence $T\sqrt{N}$ even faster than for a single time series. The point estimates can be obtained through the Ordinary Least Square (OLS) but the standard errors are non-reliable.
- The method is applicable to relatively 'short' panels compared with single time series.
- Panel cointegration (as well as panel unit root) test statistics commonly have simple distributions, e.g. standard normal.
- The use of panel cointegration also reduces the possibilities of spurious regression on two non-stationary variables.

With regard to spurious regression, Eberhardt (2009), based on Baltagi and Kao (2000), gives an analytical example as follows: suppose there are two unrelated random walks integrated to order 1, I(1), $\Delta y_{it} = \varepsilon_{1it}$ and $\Delta x_{it} = \varepsilon_{2it}$ where ε_{1it} and ε_{2it} are independent. The individual time series regression relating y and x is then expressed below:

$$y_{it} = \theta_{0i} + \theta_{1i} x_{it} + u_{it} \quad i = 1, \dots, N; t = 1, \dots, T \tag{4.13}$$

The individual time series regression is applied for each i separately, then as $T \to \infty$; the estimates for θ_{0i}, θ_{1i} will not go to zero as they should because when there are two series $\{x\}$ and $\{y\}$ integrated to order 1, $I(1)$, any linear combination of both will also be $I(1)$. The spurious regression problem becomes more apparent as the covariance of two $I(1)$ does not go to zero, even as $T \to \infty$.

[19] Most of the section is summarized from Eberhardt (2009).

To distinguish between panel data and panel cointegration, a rule of thumb, as summarized by Eberhardt (2009) based on Pedroni (2008), is shown in Table 4.5.

Table 4.5 Option of macro vs micro panel

Aspects	Macro panel	Micro panel
Also known as	Time series panel	Longitudinal panel
N (groups)	Moderate, typically <100, e.g. countries, region	Substantial, at times thousands, e.g. individuals, firms, households
T	Substantial, typically >20, e.g. years, quarters, months	Short <10, most commonly T <5; typically years
Variable properties	Unit roots, structural breaks, trends and other non-stationarities	Stationary data

Binomial probit/logit model[20] (Papers 5, 6, 8)

In this dissertation, the method is used when explaining the access or usage demand for such ICT devices[21]. The probit model estimation is employed to explain the likelihood of respondents using a certain ICT service, for instance, letting y denote the binary dependent variable. The probability of a successful event can be explained by the following eq. (4.14):

$$\Pr(y=1) = E(y) = \frac{\sum_i y_i}{N} \tag{4.14}$$

Where N is the number of observations in the sample, the probability equation from (4.14) can be translated into the probit model in the following eq. (4.15) and (4.16):

$$\Pr(y=1|x) = G\ (\beta_1 + \beta_2 X_2 + \cdots + \beta_k X_k) \tag{4.15}$$

$$\Pr(y=1|x) = G\ (x\beta) \tag{4.16}$$

where G is a function taking on values strictly between 0 and 1, $0 < G(z) < 1$, for all real numbers z. The model is often referred to in general terms as an index model because $Pr\ (y = 1|x)$ is a function of the vector x only through the index. The fact that $0 < G(x\beta) < 1$ ensures that the estimated response probabilities are strictly between 0 and 1. G is a cumulative density function that monotonically increases the index z. The function of G is presented below:

$$G\ (x\beta) = \ \Phi\ (x\beta) \equiv \int_{-\infty}^{x\beta} \phi(v)dv \tag{4.17}$$

where

$$\phi(v) = \frac{1}{\sqrt{2\pi}} \exp\ (-\frac{v^2}{2}) \tag{4.18}$$

G is the standard normal density to ensure that the probability of success is strictly between 0 and 1 for all the values of the parameters and the explanatory variables. Like the probit model, the binomial logit model is only different in terms of G , which is in logistic form.

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[20] The section is summarized from Söderbom (2010).

[21] The main difference between logit and probit is the commutative density function (CDF); logit has a logistic distribution, whereas, porbit has a standard normal distribution.

4.3. Data and summary of the methodology

Various data are used in the study (appended papers), comprising micro and macro data as well primary and secondary data. In this regard, the fact that the studies employ several different methods is not seen as an issue, as the methods are driven by the nature of the problem and the data availability. For each particular problem, the study strives to use the best method available. By construction and based on data availability, the number of the study is not equal between regions, with the majority of papers dealing with European cases. Table 4.6 gives the summary of the characteristics of the data and methodology in the study.

Table 4.6 Characteristics of the data and methodology

Aspect	Description
Time span	1975-2010.
Methodology	Mainly IO model and econometrics (panel data, panel cointegration, logit and probit model).
Source of data	Published macro data and household and individual survey data
Countries or regions	European, Asian and African regions. The studies give more emphasis on Sweden and Indonesia as case studies.

From Table 4.6, it can be concluded that the dissertation has many dimension in terms of time, methodology, source of data and countries and region investigated. To be more precise, Figures 4.2, 4.3 and 4.4 elaborate on these dimensions.

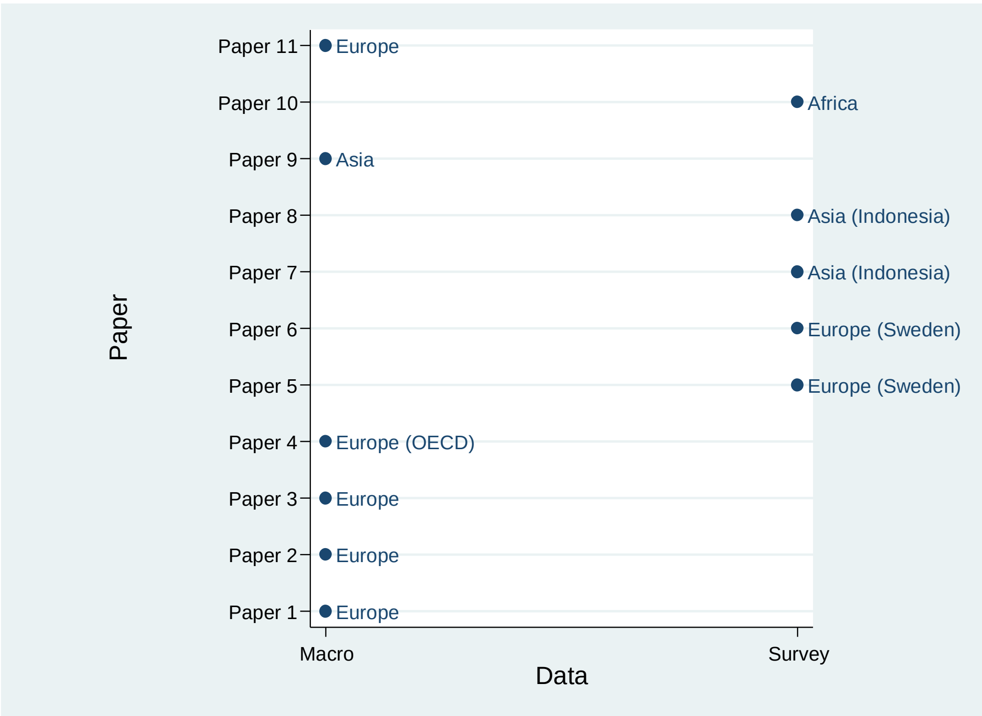


Figure 4.2 Dimension of the study based on the type of data and regions

The studies are equally distributed in terms of the types of data investigated. Five papers were written using a primary survey and six papers are based on published data in a macro level analysis. Five papers in the European study are based on macro data whereas two papers are based on survey data. For the Asian region, the paper uses macro data and two other sets based on survey data. The only study in Africa is analysed based on household survey data. Figure 4.3 illustrates the dimension of the study based on the methodology used and the region investigated.

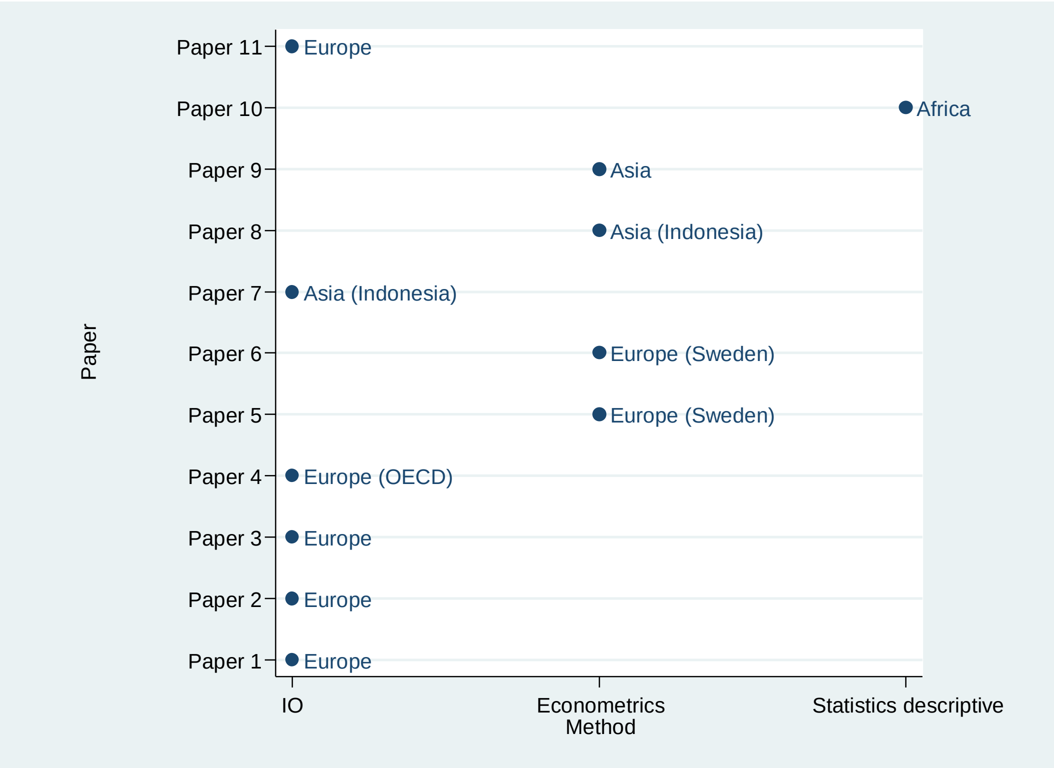


Figure 4.3 Dimension of the study based on methodology and regions

The IO model and econometric analysis use the main methodology applied in the appended papers. Six papers were written based on IO methods, of which five investigate the European region. A paper on Indonesia as a case study representing the Asian region also adopts such a method. Econometric analysis is applied to four papers equally distributed between Asia and Europe. A paper on Africa is also investigated using a statistic descriptive by applying cross-tabulation and the Gini coefficient measurement. Next, Figure 4.4 shows the dimension of the study based on time and regions.

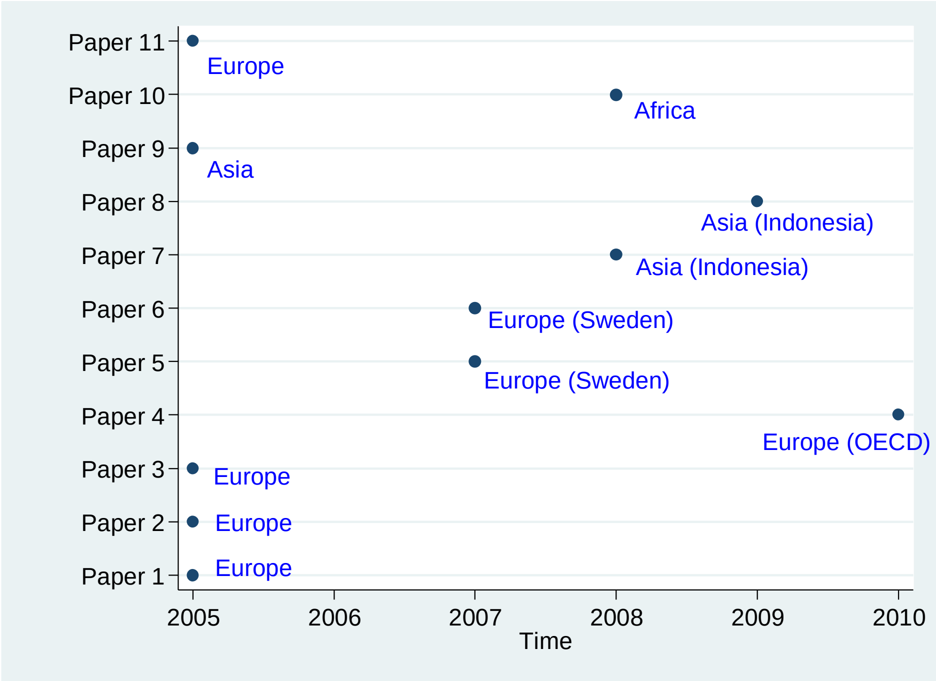


Figure 4.4 The dimension of the study based on time and regions

The illustration based on Figure 4.4 only shows the end year of observation while some papers employ a long time series for the investigation. In general, the range of time series that ended in 2005-2010 enables better analysis in picturing the more recent phenomenon of ICT production and diffusion in each region. Table 4.7 gives a summary of data used, time frame and methodology in a more detailed exposition.

Table 4.7 Methodology and sources of data

Paper	Method	Description of the data	Country(ies)/Region	Time frame	Source	Example of previous studies employing the same methodology
Paper 1	Input-output analysis Multiplier analysis	59 sectors of the IO table	11 selected European countries[22]. The countries are Austria, Denmark, Finland, France, Germany, the Netherlands, Spain and Sweden.	1995, 2000 and 2005	Eurostat	Inklaar, Timmer, Van Ark, 2007; Bazzazan, 2009
Paper 2	Input-output analysis Multiplier analysis and Decomposition analysis					
Paper 3	Input-output analysis Multiplier analysis and Decomposition analysis and price elasticity					
Paper 4	Panel data analysis	Socio-economic variables and speed data	34 OECD countries	2008-2010 (quarterly data)	OECD, the World Bank; speed data are obtained from Ookla	Torero, Chowdhury and Bedi, 2002; Ding and Haynes, 2006; Karner and Onyeji, 2007; Lam and Shiu, 2010; Gruber and Koutrompis, 2011
Paper 5	Probit model	The longitudinal household survey data from PTS comprises 9247 respondents in total.	Sweden	2002-2007 (annual survey)	PTS annual household survey	Forman and Goldfarb, 2005; Grazzi and Vergara, 2008; Arduini et al., 2010
Paper 6	Probit model	The household survey comprises a postal survey (total of 764 respondents) and an Internet survey (total of 495 respondents).	Sweden	2007	Chalmers mobile barometer survey	

[22] Eleven European countries are chosen based on the assumption that they have an advanced level of technological development (Eichengreen. 2008). Given the limited data for some countries in a particular year and due to the decomposition analysis requiring at least two time periods to enable investigation, the complete analysis is only applied to eight countries that have complete sets of data for 1995, 2000 and 2005.

Paper 7	Input-output analysis Multiplier analysis and decomposition	The 80 sectors of IO table	Indonesia	1975, 1980, 1985, 1990, 1995, 2000, 2005 and 2008	Central Bureau of Statistics Indonesia (Badan Pusat Statistics) and the Institute for Economic and Social Research, University of Indonesia	Same as papers 1, 2, 3
Paper 8	Probit model	Household survey data comprising 3470 respondents, and covering urban and rural, and 4 main islands in Indonesia (Java, Sumatera, Kalimantan, and Sulawesi)	Indonesia	2009	Ericsson Consumer labs	Same as papers 5 and 6
Paper 9	Panel cointegration	Socio-economic variables data and ICT diffusion. The number of countries is 35 over the period 1980 to 2008, while the cointegration test omits some countries with missing values, hence the time span is 1983-2006.	Asia Pacific countries	1983-2005 (time series)	ITU and the World Bank	López-Pueyo, Barcenilla-Visús and Sanaú, 2008; Venturini, 2009; Chakraborty and Nandi, 2011
Paper 10	Descriptive statistics	Household survey data	14 Africa countries: Senegal, Burkina Faso, Benin, Côte d'Ivoire, Zambia, Mozambique, Tunisia, Uganda, Tanzania, Kenya, Ethiopia, Ghana, Namibia and South Africa	2008	Research ICT Africa	UNECA, 2000, Higgins and Williamsson, 2002
Paper 11	Input-output analysis Multiplier analysis on IPTV	59 sectors of IO table	11 selected European countries	1995, 2000 and 2005	Eurostat	Same as papers 1, 2, 3

4.4. Limitation

4.4.1. On the input-output methodology

The IO method is the most important methodology adopted in this study. The method has been used for the majority of the appended papers in this dissertation. So far, the study has explored the strength of the IO method in detailed analyses. It is also a fair exposition to see the possible drawback of the method. Hastings and Brucker (1993) mentioned some basic assumptions when the IO method was employed in a study, for instance: (i) industry production is a linear process in which changing the output neither creates economies nor diseconomies of scale, (ii) each industry creates only one product, thus for multi-product firms, the output is represented by the primary product produced during the production process, (iii) each product is produced by a fixed process, hence different firms producing the same product are assumed to comply with the same process, (iv) changes in price will not affect the input proportion, only changes in the final demand affect the inputs to production, (v) the inputs are infinite, and (vi) excess capacity in firms is not the case as the demand and supply are assumed to be in equilibrium. While these assumptions do not limit the ability of the method to investigate the impact on the economy (Taylor, Winter, Alward, & Siverts, 1992; Miller & Blair, 2009, p.13), the assumptions can be seen as too restrictive to capture the dynamic of the ICT economy.

It also has to be borne in mind that on theoretical grounds, the calculation of the IO table corresponds to the complete sets of income and product accounts for the economy (Miller & Blair, 2009, p.13). In practice, however, it may not always be the case. Zhilong (2008) presents the complexities of using the IO model on the Chinese economy, especially related to the synchronization of the IO and other national account calculations. For instance, instead of leading the other indicators, the IO survey is just intended to estimate the ratio (estimating base) not the base of the GDP calculation. Hence, instead of the IO survey or IO table serving the GDP estimation, in practice, the GDP calculation turns into a control for the data of the corresponding part of the IO table.

With regard to the reliability of the analysis from product or industry level, it was advised by Inklaar (Inklaar, R., personal communication, email, January 25, 26, 2010) that the problem of aggregation is the most important aspect to take into account when estimating the economic impact of a particular product. In the case of the deployment of a particular ICT device (e.g., broadband, IPTV), for example, the investment shock may come from the wire and cable industry even though, in some minor part, it represents the construction sector. For second-stage effects, it is not immediately clear where such activities would show up, as there is also a broadcasting industry and other related sectors. The conclusion is that it is a requirement to have a very detailed input-output table in order to grasp the impact on a product basis.

4.4.2. On multidimensional aspects of time, data and regions

The study tries to portray the ICT sectors in terms of production and diffusion in three regions – Europe, Asia and Africa – with the ultimate goal of identifying the problem faced by each region and possible strategies to respond to these problems. To achieve the purpose of the study, various data in different time frames and regions are gathered. Some case studies are carried out to exemplify and give more emphasis to the phenomenon of ICT production and diffusion in each region. As discussed in Chapter 4, the fact that the studies employ several different methods is not seen as an issue, as the methods are driven by the nature of the problem and the data available. For each particular problem, the study strives to use the best method available.

However, it has to be admitted that different time frames and methods correspond to different levels of generalizability due to the region and time delimitation, with the same case studies directed to observe specific countries in particular time series. Longer time series in some papers also mean that the phenomenon is seen as more structural, especially when IO methodology is employed. These characteristics are especially attributable to Papers 1, 2, 3, 7 and 11. These papers are aimed at investigating the problem of the ICT sectors in the European and Asian regions. On the other hand, some papers using cross-section data based on household survey (Papers 5, 6, 8 and 10) only draw a snapshot of the phenomenon at a particular time. These papers aim to identify specific strategies to respond to the problems. While the problems obtained from the study are generally at structural level, the strategies offered are therefore generally more instantaneous, even though they are not linked to each other.

Chapter 5 Empirical results

This chapter is divided into two parts. The first section discusses the research questions concerning the context in the European region, whilst the second section elaborates on the research questions on Asia and Africa. The empirical results are presented based on sub-research questions on Chapter 3 on the production and diffusion of ICT sectors in Europe, Asia and Africa.

5.1. On the European economy

5.1.1. Production of ICT sectors

There is a sub-research question concerning production of ICT sectors in the European region. The question relates to the fact that ICT sectors contributed little to the overall economy and productivity level (compared with the United States). The question is therefore formulated as follows:

How can the declining contribution of the output of the ICT sectors in the European countries' economy in the 1995-2005 period be addressed and what particular problems does the European region face concerning the slowdown of the impact?

The empirical analysis is based on Papers 1, 2 and 3. First, the descriptive analysis from the IO table is presented to see the position of ICT sectors in the European economy. Table 5.1 compares the growth rate of the ICT sectors with the average growth rate of other sectors in the European economy.

Table 5.1 Growth of output

	1995-2000	2000-2005
Economic output	4.89%	2.37%
ICT sectors	7.31%	2.33%

From Table 5.1, the output growth of the ICT sectors in the European countries generally follows the pattern of the other sectors. It means that when the growth of the economy decreased from 4.89% during 1995-2000 to 2.37% during 2000-2005, the growth of the ICT sectors' output also dropped off from 7.31% during the first period to only 2.33% in the second sub-period. However, it has been found that the ICT sectors dropped off much more than the rest of economy during the second period. The following analysis then investigates the output multiplier for ICT sectors compared with non-ICT sectors in the European economy.

Table 5.2 Multiplier effect

Year	ICT	Non-ICT
1995	1.53	1.58
2000	1.57	1.62
2005	1.57	1.61

It can be accentuated based on Table 5.2 that, following the definition of *output multiplier*, for each 1 euro spent in the ICT sectors, final demand enabled an increase in economic output of as much as 1.53 euro in 1995. The finding indicates that in general the output multiplier of the ICT sectors is, in fact, smaller than that of non-ICT sectors. The findings send the message that the ability of ICT sectors to affect the size of economic output is considered lower than that of non-ICT sectors.

Next, the decomposition analysis is applied to trace the possible source of the problem, having found that the ICT sectors contributed less to the over-all economy. The results of the decomposition analysis during two periods of observation are presented below:

Table 5.3 Decomposition of output change in millions in the specified unit of currency (1995-2000)

Countries	Domestic final demand effect	Export effect	Import substitution effect	Technological change effect	Total	Currency
Austria	23,908.40	11,380.35	13,426.21	-4,457.78	47,886.00	EUR
Belgium	17,931.65	21,313.76	-3,723.46	5,192.48	40,714.42	EUR
Denmark	64,861.24	70,072.11	-38,004.72	-32,838.56	64,090.08	DKK
Finland	10,443.54	12,602.41	272.88	3,023.50	26,342.33	EUR
France	121,116.87	71,960.40	-19,874.15	22,448.77	195,651.89	EUR
Germany	127,779.24	112,115.85	-43,424.55	17,465.95	213,936.49	EUR
The Netherlands	21,119.03	18,087.05	-5,413.02	5,901.17	39,694.23	EUR
Spain	60,978.96	30,813.71	17,769.86	15,178.14	124,740.67	EUR
Sweden	210,291.53	218,247.61	-185,573.53	93,914.54	336,880.15	SEK

Table 5.4 Decomposition of output change in millions in the specified unit of currency (2000-2005)

Countries	Domestic final demand effect	Export effect	Import substitution effect	Technological change effect	Total	Currency
Austria	8,033.11	5,427.39	162.76	4,119.74	17,743.01	EUR
Denmark	27,737.36	14,375.22	(3,666.26)	7,872.21	46,318.53	DKK
Finland	3,904.90	2,054.11	(4,467.80)	664.89	2,156.10	EUR
France	36,774.92	(8,924.68)	(6,602.56)	24,702.56	45,950.24	EUR
Germany	38,664.14	74,957.75	(68,036.99)	(42,551.83)	3,033.07	EUR
Italy	10,827.89	4,221.06	(4,730.03)	12,591.31	22,910.23	EUR
The Netherlands	12,820.59	7,690.18	(3,304.06)	4,310.22	21,516.93	EUR
Norway	10,520.58	(1,269.10)	1,512.02	(18,572.43)	(7,808.92)	EUR
Spain	74,629.01	16,470.84	1,380.26	7,318.77	99,798.87	EUR
Sweden	62,807.11	(18,054.23)	(28,340.64)	(19,311.49)	(2,899.25)	SEK

The decomposition analysis in Table 5.3 shows that the change in the ICT sectors' output during the period 1995-2000 was heavily influenced by domestic demand and the export effect. Correlated with the size of the individual country's economy, the domestic demand and export effect are associated with population size and GDP. Hence, countries like Germany, France, Spain and Austria show a higher domestic final demand effect. Furthermore, there is a clear indication that most of the European countries were adopting outward-looking approaches to building the ICT sectors in the sense that there is a clear strength of export effect boosting the ICT sectors' output. Belgium, Finland, Sweden and Denmark are the countries that have large export effects compared with domestic final demand. On the other hand, the import substitution effect is generally negative (countries also importing ICT products), except for Finland and Spain. To sum up, given that the impact of the export effect is greater than that of the import substitution, the results confirm that European countries have a strong comparative advantage in these sectors.

Looking at Table 5.4, however, the performance of the ICT sectors in the European countries is weakened in every aspect during the period 2000-2005. The change in the ICT sectors' output has mainly been driven by the domestic final demand effect, which has declined compared with the previous period. The export effect also decreased, with the ICT sectors in Sweden and Norway recording quite substantial negative impacts. This means that, in general, the comparative advantage of ICT products exported to the rest of the world has been declining. Furthermore, 7 out of 10 countries investigated show a positive import substitution effect, meaning that these countries were penetrated by imported ICT products from other countries. The technological effect remains positive in some countries, but with a lower value.

Besides the lower export effect, the European countries also experienced a lower technological change effect of the ICT sectors in the later period, which means the ICT sectors are less able to affect the production process and technology used in the other sectors, as shown in Figure 5.1:

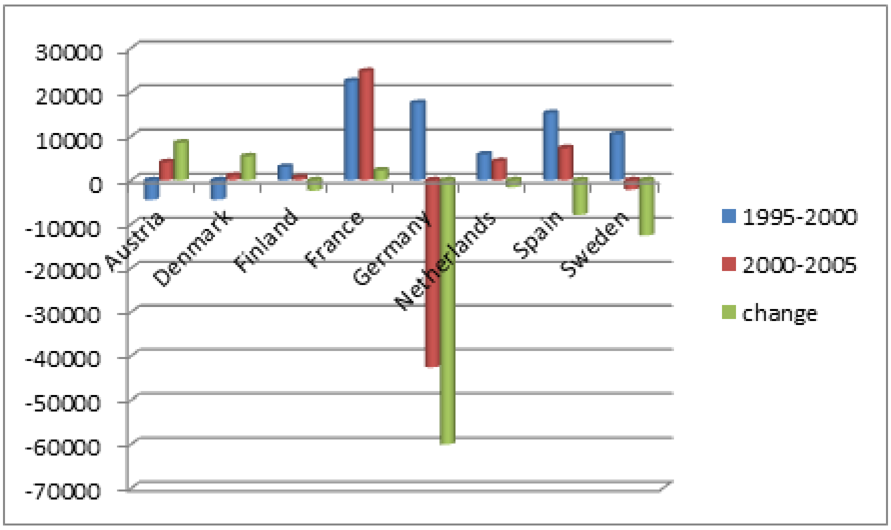


Figure 5.1 Technological change effects 1995-2000 and 2000-2005 (M EUR)

Figure 5.1 shows that the technological change effect has largely vanished in the European economy. Austria and Denmark are the only countries that successfully changed their technological change effect from negative to positive, whereas France is considered to have the most stable technological change effect between two periods. The other countries that are still able to obtain positive values are Finland, the Netherlands and Spain. For the majority of the countries, however, the technological change effect became smaller or even disappeared from the economy, shown most clearly in the case of Germany, Sweden, the Netherlands and Spain.

This dissertation finds that the lower technological change effect is also related to disconnection between the ICT sectors and the rest of the economy as pictured in Figure 5.2, which is obtained employing the causative matrix analysis of the IO table (equation 4.6)

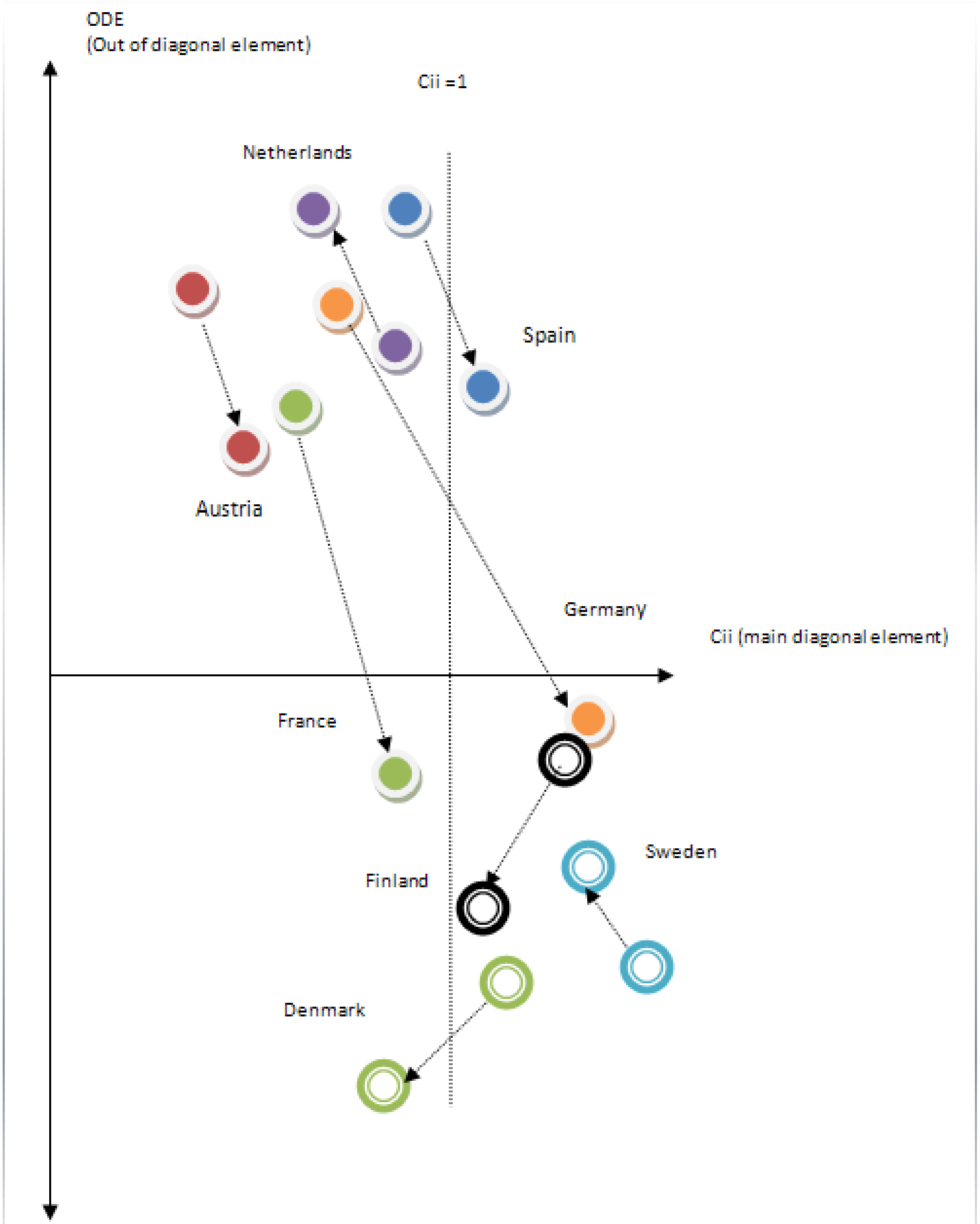


Figure 5.2 Transition of ICT sectors in the European countries

Figure 5.2 shows irregularity of the structural change and the transition of ICT sectors in 1995-2000 and 2000-2005. The patterns can be summarized as follows[23]:

- Northwest quadrant: the ICT sectors are becoming more externalized while at the same time receiving more feedback from the non-ICT sectors
- Southwest quadrant: the ICT sectors are becoming more externalized while at the same time receiving less feedback from the non-ICT sectors
- Northeast quadrant: ICT sectors are becoming more endogenized while at the same time receiving more feedback from the non-ICT sectors

[23] The quadrant is divided into four categories for which Cii=1 and ODE=0 are the threshold values for the indicators.

- Southeast quadrant: ICT sectors are becoming more endogenized while at the same time receiving less feedback from the non-ICT sectors

Thus, based on the direction of the transition patterns, the structural change in the ICT sectors in each country can be categorized as in Table 5.5.

Table 5.5 Category of country based on the direction of the path of the ICT sectors

More externalized and more feedback (1)	**More externalized and less feedback (2)**	**More endogenized and more feedback (3)**	**More endogenized and less feedback (4)**
Sweden The Netherlands	Finland Denmark		France Germany Spain Austria

Table 5.5 shows that most countries with big economies (France, Germany and Spain) fall into group four, which means that the ICT sectors are endogenized. Thus, the ICT sectors are more unrelated to non-ICT sectors while at the same time having less impact from other non-ICT sectors. In terms of the sectoral analysis, Table 5.6 explains the classification of ICT sectors based on a causative matrix analysis.

Table 5.6 Category of ICT sectors based on the direction of the path of the causative matrix

More externalized and more feedback (1)	**More externalized and less feedback (2)**	**More endogenized and more feedback (3)**	**More endogenized and less feedback (4)**
Machinery and equipment Research and development services Education services	Wholesale trade and commission trade services, except motor vehicles and motorcycles	Medical, precision and optical instruments, watches and clocks	Electrical machinery and apparatus Radio, television and communication equipment and apparatus Office machinery and computers **Postal and telecommunications services** Computer and related services Printed matter and recorded media

Table 5.6 shows that from the point of view of the sectoral analysis, the results also confirm the country analysis. Most of the ICT sectors in the European economy were found to be categorized as more endogenized and having less feedback. This means that the connection between the sectors

and the rest of the economy is smaller and that the feedback from other sectors stimulating the output of the ICT sectors is also minimized. This study also finds that the common example of ICT sectors (telecommunication) is in the endogenized sectors.

5.1.2. Diffusion of ICT devices

The analysis on the diffusion side in the European region is based on two backgrounds: the growing concerns that the European region lacks innovation and the need to understand the demand side analysis of new ICT services.

On the demand side

The following section concerns the demand side discussion, which is seen as an important analysis to close the digital gap but is not generally taken into the policy consideration very much (Preston, Kerr & Cawley, 2009; Taaffe, 2011). Narrowing the discussion on cellular devices, the European cellular market is found to be conservative with a smaller degree of innovation (Scuka, 2003). The research question is formulated below:

As demand analysis is generally left behind in understanding the diffusion of technology; what is the future of new services in ICT devices?

This sub-research question is addressed in Papers 5 and 6. Sweden is taken as a case study to answer this research question, since the country is seen as mature in terms of ICT and, particularly, mobile telephony. Mobile telephony was introduced early in Sweden and since 2001 it has had one of the highest rates of mobile penetration in Europe along with Finland and Norway (Andersson, Hulten & Valiante, 2005). During the development of mobile telephony, the industry in Sweden has applied several different systems and technologies (Mölleryd, 1999).

Paper 5 first identifies the extent to which the current diffusion of the three biggest cellular operators has been spread throughout Sweden. The results are based on a logit estimation of the decision to subscribe to a particular operator presented in Table 5.7.

Table 5.7 Diffusion of cellular subscriptions based on operators in Sweden

Socio-economic variables	Operator		
	A	B	C
Income			
High	X		
Middle		X	
Low			X
Education			
High		X	X
Middle	X		X
Low			
Age			
Elderly			
Middle age			
Teenager	X	X	X

Sex			
Male			X
Female		X	

The results shown in Table 5.7 indicate that the diffusion of cellular subscriptions has been spread to all operators based on the socio-economic characteristics of the users. There is an indication, however, that the elderly have been left out of the mapping. In terms of age, all three operators assigned in the study are more interested in teenagers or, to express it in another way, the features and services are best suited to teenagers as the market segment. Though middle age people are also left out of the mapping, they are generally also attributable to middle to higher income so the problem becomes less serious for middle age users than for the elderly. This study follows Vicente and Lopez's (2008) findings that, in general, the diffusion of ICT devices has excluded the elderly in the case of the European region.

Paper 6 continues the analysis by predicting the type of future cellular services in Sweden. The estimation employing probit on the decision to adopt new cellular services is presented in Table 5.8

Table 5.8 New cellular services in Sweden based on the socio-economic characteristics of the users

Determinants	**Devices**
Income	
Higher income	Mobile TV Mobile games Mobile news Mobile Internet
Lower-middle income	Mobile video Mobile payments
Sex	
Male	Mobile TV Mobile news Mobile Internet
Female	Mobile games
Education	
Higher education	Mobile games Mobile news Mobile Internet Mobile video Mobile payments
Lower middle education	Mobile TV

The empirical analysis shown in Table 5.8 concluded that new services will be adopted differently based on the characteristics of the user. The study figured out that male subscribers with a higher education and subscribers living in a small city are a potential niche market for new services in Sweden. Related to this finding, the other study conducted by Rohman and Bohlin (2011) investigates future cellular services in Sweden.

Table 5.9 Future cellular services

No	Mobile services	Description
1.	Mobile text	Words spoken into the cellular device are automatically converted into email text or received email can be read aloud.
2.	Mobile map	The current location is shown on the cellular screen, and local weather, traffic and store information are also displayed.
3.	Mobile customized information	Information on living areas and living patterns that have been registered in advance and information matching the subscriber's tastes can be received on the cellular phone.
4.	Mobile VOD	Movies can be watched anywhere, anytime on the mobile screen.
5.	Mobile TV	TV can be watched anywhere, anytime on the mobile screen.
6.	Mobile content	The cellular device can be used to publish stories, illustrations, photos, etc. that the user has created for others to view.
7.	Mobile concierge service	The cellular phone will ring to inform the user of a scheduled event or tell him/her the shortest route to his/her destination, to support the subscriber's daily activities, much like a secretary.
8.	Mobile health support	Based on the information entered regarding the user's personal health, the cellular phone will provide advice on exercise and what to eat.
9.	Mobile friend	The cellular phone will keep the user regularly informed of the names of friends he/she has not been in touch with recently.

Table 5.10 presents the results based on a discrete choice of the probit model, questioning whether the respondents are interested in the new services listed in Table 5.9.

Table 5.10 Demand for future cellular services

	Marginal effect								
Explanatory variables	**Mobile friend**	**Mobile TV**	**Mobile text**	**Mobile map**	**Mobile customize**	**MVOD**	**Mobile content**	**Mobile concierge**	**Mobile health support**
Medium income	-0.022	0.031	0.045	0.029	0.049	0.028	-0.026	0.131***	0.044
	-0.011	*0.031*	*0.081*	*-0.000*	*0.0984****	*0.054*	*0.018*	*0.144*****	*0.075***
High income	0.015	0.065	-0.059	-0.060	-0.040	0.015	-0.137**	0.1176**	0.037
	0.013	*-0.082*	*-0.072*	*-0.108*	*-0.032*	*0.016*	*-0.133*	*0.114***	*0.030*
Age less than 25	0.211**	0.348***	0.051	0.179***	0.365***	0.437***	0.423***	0.256***	0.145
	0.187	*0.448*****	*-0.038*	*0.198*****	*0.405*****	*0.545*****	*0.471*****	*0.279*****	*0.178*
Age 25-50	0.088***	0.257***	0.050	0.187***	0.209***	0.23***	0.237***	0.192***	0.119***
	*0.069****	*0.227*****	*0.055*	*0.209*****	*0.255*****	*0.215*****	*0.249*****	*0.248*****	*0.177*****
Years of education	-0.025	0.016	-0.013	0.036	-0.045	-0.001	0.08**	-0.029	-0.019
	-0.026	*0.016*	*0.054*	*0.0898*****	*-0.062*	*-0.038*	*0.089***	*0.041*	*-0.041*
Number of children	-0.009	0.016	-0.007	-0.009	0.000	-0.010	-0.009	0.002	-0.010
	0.003	*0.026*	*-0.019*	*-0.027*	*0.003*	*-0.007*	*-0.008*	*0.001*	*-0.011*
Male	0.026	0.006	0.064	0.030	0.062	-0.027	-0.023	0.032	-0.043
	0.030	*0.008*	*0.065*	*-0.040*	*0.068*	*-0.024*	*-0.013*	*0.032*	*-0.041*
Married	0.013	-0.010	0.042	0.029	-0.006	-0.022	0.005	0.005	0.020
	0.000	*-0.030*	*0.058*	*-0.048*	*-0.007*	*-0.007*	*-0.030*	*0.003*	*0.003*
Respondents in big	0.044**	0.055	0.066	0.012	0.106***	0.042	0.050	-0.017	0.012

cities									
	*0.049**	*0.081**	*0.066*	*0.066*	*0.156****	*0.048*	*0.080*	*-0.016*	*0.025*
Occupation	0.014	0.004	0.003	0.074**	-0.038	-0.013	-0.046	-0.038	-0.006
	0.008	*0.026*	*0.022*	*0.802****	*-0.045*	*-0.025*	*-0.065*	*-0.066*	*-0.055*
Length of having cellular phone	0.003	0.006	0.011**	0.006**	0.007	0.004	0.000	0.007	0.000
	0.002	*0.004*	*0.011****	*0.008*	*0.004*	*0.000*	*-0.004*	*0.013***	*0.003*
Heavy Internet users	0.003	0.171**	-0.039	-0.048	0.088	0.116**	0.010	-0.009	0.1306**
	0.040	*0.213****	*-0.075*	*-0.026*	*0.143**	*0.222****	*0.071*	*0.067*	*0.230****

Note: The numbers in italics represent the marginal effects of weighted probit regression and ***, **,* represent significant at the 1%, 5% and10% levels respectively.

Source: Rohman and Bohlin (2011)

The econometric testing conducted in the Swedish market, as shown in Table 5.10, draws several conclusions in relation to the demand for future cellular services:

- Top three future services that respondents currently demand: mobile map, mobile concierge and mobile customize information.
- Age classification is an important variable as almost all kinds of services, particularly mobile maps, mobile customize information, TV, VOD and mobile content are influenced by teenagers.
- The income level is surprisingly less important when projecting future cellular services.
- The future of cellular services is gender-neutral as no particular gender is found determining future usage in Sweden.
- The geographical area (differences between small and big cities) is seen as an important driver, e.g. mobile friend and mobile TV and customized information.

5.2. On the Asian and African regions

5.2.1. Production of ICT sectors

One question concerning ICT production is about the fact that some Asian countries are yet to gain the positive impact of the investment in ICT sectors (Wong, 2002; Kuppusamy, Pahlavani & Saleh, 2008). Indonesia is an example of this phenomenon. The sub-research question is formulated as follows:

What might be the problem as some countries are still unable to benefit from ICT investment in Asia?

This question is investigated in Paper 7. Since the definition of ICT sectors based on that of the OECD (2009) seems irrelevant to classify the sectors in developing countries. This study simplifies the sectors by only taking ‘telecommunication’ as the case. As in the previous section dealing with the production side in Europe, the measurement comparing the multiplier of the telecommunication sector and the average economic sector is assessed first. The structural break called ‘cellular era’ denoted by the period at which the penetration rate of cellular devices surpassed the fixed line is added to distinguish the analysis before and after. The result is shown in Figure 5.3.

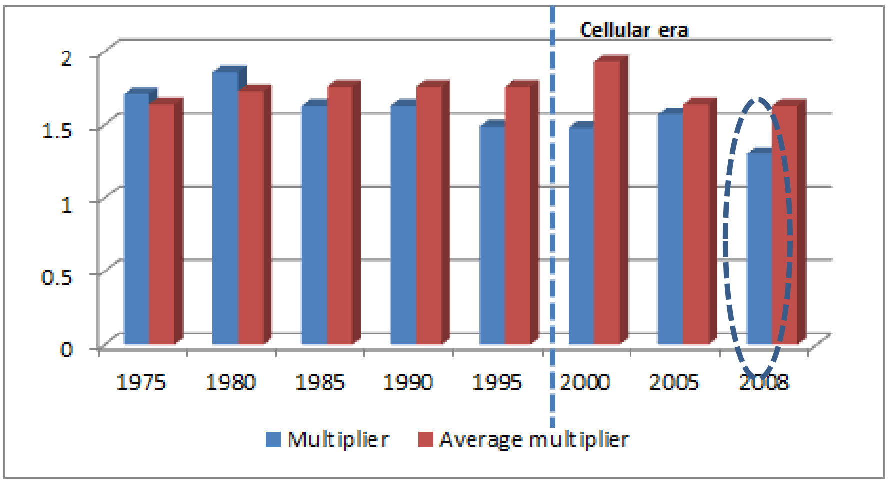


Figure 5.3 Multiplier for the telecommunication sector in Indonesia compared with that of other sectors

From Figure 5.3 it can be concluded that the coefficient multiplier of the telecommunication sector is generally about 1.6 for the 1970s to the 2000s. This means that an increase of 1 IDR in final demand in the telecommunication sector corresponds to an increase in the total output of as much as 1.6 Indonesian Rupiah (IDR). Nevertheless, it is quite surprising that the multiplier has gradually decreased since the 1980s. As the sector has seen massive development thanks to cellular telephony, it has generally gone unnoticed that the majority of the telecommunication service is consumed as final demand with little increment in the intermediate demand affecting the other sectors. With the growth of the cellular era in 2000, the multipliers are even smaller. Compared with the average multiplier, Figure 5.4 concludes that in 2008, the telecommunication sector had a smaller coefficient than the previous observations at times when the cellular penetration rate reached 70% (about 150 million subscriptions).

To see the change in output, Figure 5.4 presents the decomposition analysis of the telecommunication sector in Indonesia.

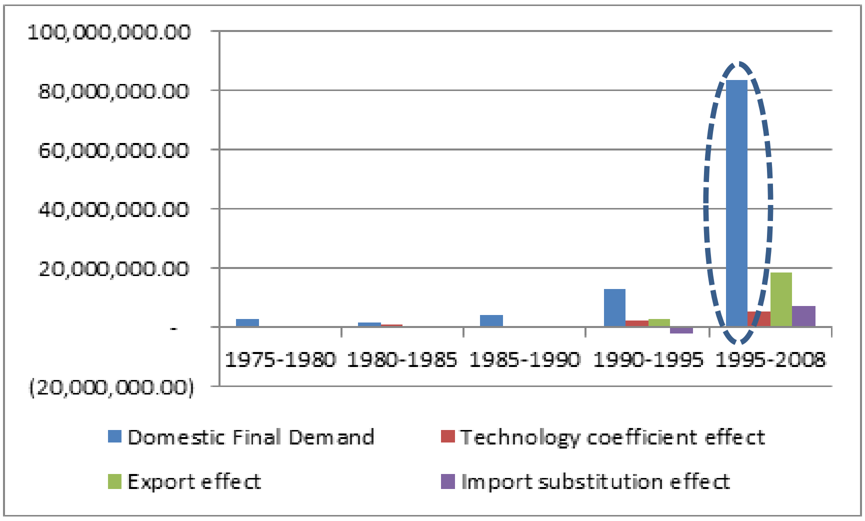


Figure 5.4 Decomposition analysis of the telecommunication sector (M IDR)

Figure 5.5 depicts the decomposition analysis that shows that the greater portion of the output is in the form of domestic final demand throughout the periods. The cellular era is denoted by the change in output from 1995 to 2008. During the period, the figure shows an even greater source of growth from domestic final demand and a very small portion from the technological change effect. In other words, given that the majority of the output is consumed as final demand, the role of telecommunications in supporting other sectors through intermediate demand (playing its role as GPT) is considered low.

5.2.2. Diffusion of ICT devices

On questioning the impact of ICT diffusion on quality of life and socio-economic variables

The research question is driven by the current phenomenon showing that the diffusion of ICT devices (amid a huge digital gap between countries) is generally more pronounced in Asia. On the other hand, the development of socio-economic variables is generally left behind. Thus, the formulated research question is:

Have the adoptions of ICT devices in Asia led to better socio-economic variables, in particular health and education?

Based on Paper 9, the analysis in Asia is conducted employing a panel cointegration technique by first identifying the stationary of the data (Maddala & Wu, 1999). The method does not require balanced panel data, though the later stage on cointegration analysis does. The series on the unit root test therefore covers all countries (35 in all) over the period 1980 to 2008, while the cointegration test omits some countries with missing values and investigates the problem in a shorter time period (1983-2006). Some interpolations are also appended to the countries that have long series but face gaps in certain periods. The results are shown in Table 5.11.

Table 5.11 Cointegration analysis between ICT and socio-economic development

Cointegration		Westerlund statistics[24]	ICT penetration rate		
			Internet	Fixed telephony	Telephony (cellular & fix)
Socio-economic variables	Health (life expectancy rate)	Gt	9.186 (1.000)	14.967 (1.000)	15.578 (1.000)
		Ga	3.724 (1.000)	3.806 (1.000)	3.565 (1.000)
		Pt	10.038 (1.000)	13.046 (1.000)	12.748 (1.000)
		Pa	1.841 (0.967)	2.137 (0.984)	1.854 (0.968)
	Education (primary education attainment)	Gt	NA	1.073 (0.858)	1.250 (0.894)
		Ga		3.104 (0.999)	3.139 (0.999)
		Pt		1.629	3.983

[24] The Westerlund cointegration statistics provide four statistical measurements putting the null Hypothesis (H0) as no cointegration. These results can be rejected at the 10% threshold for the first two series of Westerlund statistics (Gt and Ga) and at the 5% threshold for the last series of statistics (Gbaguidi, 2008). The numbers reported above are only the Z-value and the p-value.

				(0.948)	(1.000)
		Pa		1.367 (0.914	1.564 (0.941)
	Education (female in primary education)	Gt	NA	5.001 (1.000)	5.523 (1.000)
		Ga		3.225 (0.999)	3.217 (0.999)
		Pt		2.701 (0.997)	2.027 (0.979)
		Pa		1.411 (0.921)	1.383 (0.917)

Table 5.11 reports the results of cointegration between ICT development (column: represented by the Internet penetration rate and telephony) and socio-economic development (row: health and education). With the null hypothesis stating that there is no-cointegration, it can be concluded that given the higher p-value compared with the critical value (5%), there is no evidence that any of the ICT devices have a long-term relationship with education and health.

Africa region

The analysis in Africa focused on the diffusion side, particularly to see whether the impact of ICT diffusion on cellular and Internet access has led to a better quality of life (QOL) in terms of household income, participation and productivity as discussed in Paper 10. Figure 5.5 pictures the simulation of the Gini coefficient and Lorenz curve based on four different scenarios for the respondent: with a cellular device; with the Internet; with both devices; and with neither device. The analysis employs the Gini coefficient to measure the income distribution between citizens. The Gini coefficient, derived from the study by Corrado Gini in 1912, shows the distribution of income (Gini, 1912). The inequality distribution ranges from a value of 0 to 1, with the lower Gini indicating full equality while a value of 1 shows maximum inequality. The technical measurement of the indicator is calculated on the basis of the Lorenz curve. The curve draws the proportion of the total income of the population (y-axis) that is cumulatively earned by the bottom x per cent of the population. The line at 45 degrees pictures perfect equality of incomes. The Gini coefficient is therefore the ratio of the area that lies between the line of equality and the Lorenz curve.[25]

[25] The measurements of the Gini index and the Lorenz curve are explained as follows. Assuming that the area between the line and the perfect equality of the Lorenz curve is A and the area under the Lorenz curve is B, the Gini coefficient is measured as $A/(A+B)$ (Stiglitz, 1997). Consequently, the coefficient can also be calculated as $= 2A = 1 - 2B$, since $A + B = 0.5$. In addition, if the Lorenz curve is the function of $Y = L(X)$, then the Gini coefficient will satisfy the following eq. (1):

$$G = 1 - 2\int_0^1 L(X)\,dX \qquad (1)$$

Moreover, in survey data in which there is a random sample of S consisting of the values $y_i, i = 1$ to n and the index is in ascending order ($y_i \leq y_{i+1}$), the Gini coefficient is formulated as in eq. (2).

$$G(S) = \frac{1}{n-1}\left(n + 1 - 2\frac{\sum_{i=1}^{N}(n+1-i)y_i}{\sum_{i=1}^{n} y_i}\right. \qquad (2)$$

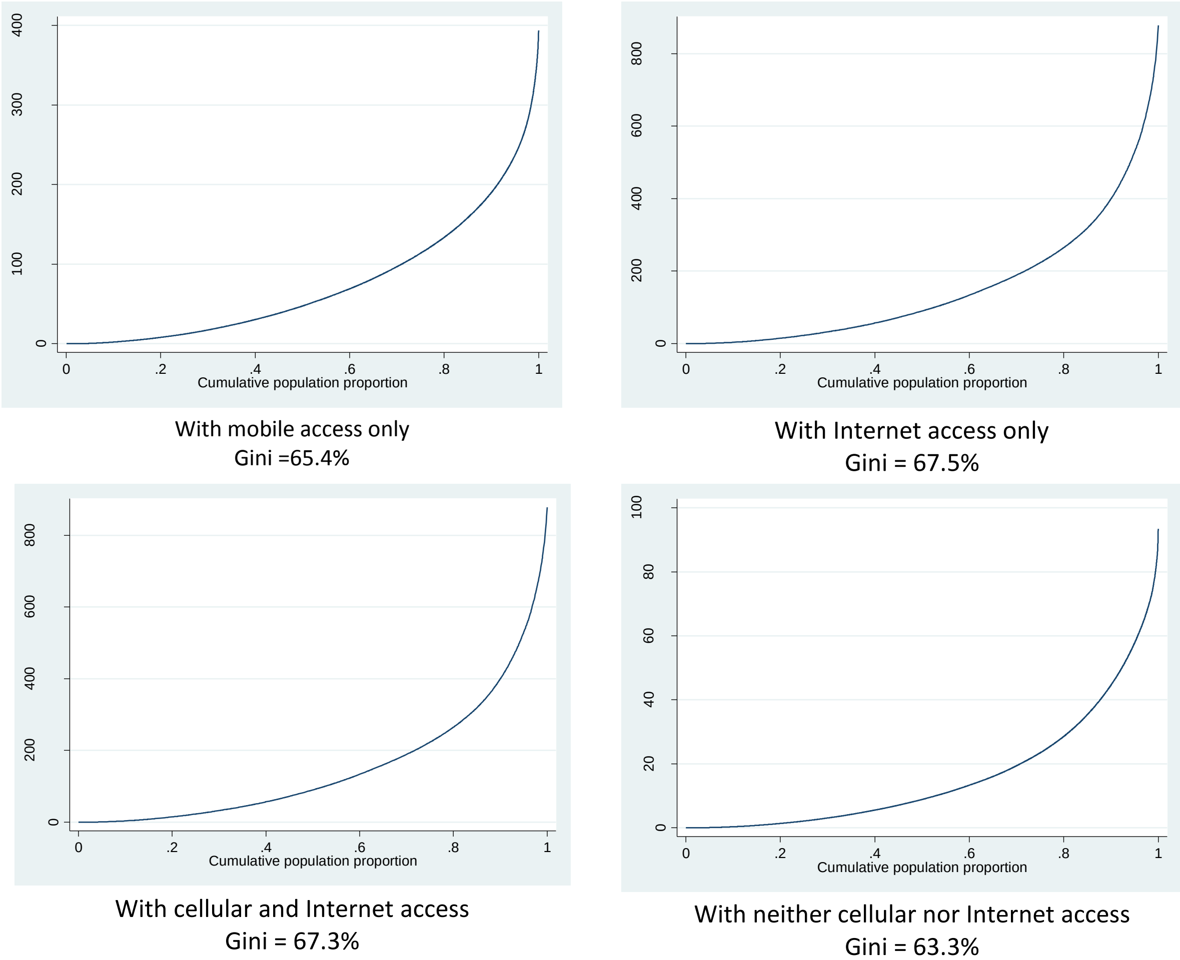


Figure 5.5 Shape of the Lorenz curve and the Gini coefficient with and without access to devices

From Figure 5.5, it was found that that inequality of income is not significantly different based on scenarios adopted in the analysis. Nevertheless, cellular access has the edge on closing the gap of income inequality indicated by the coefficient, which is lower than that for the Internet (65% compared with 67%). The impact on self-reported participation and productivity is similar with no strong evidence that access to both devices is enough to motivate users to be more involved and more productive.

Related to Africa, Paper 10 concluded there is a need to design policies for the telecommunication sector in the countries with a stronger connection between access to and use of the devices and economic activities. The policy should also aim to reduce the polarization of access and use by providing a telecommunication infrastructure in all the countries, thereby decreasing the cost of access and usage. Such policies require close collaboration between governments and the private sector.

5.3. Strategies

The empirical analysis presented in this study has investigated, in more depth, the problems faced by each region concerning production and diffusion of the ICT sectors. However, not all problems are supported by strategies and policies in the appended papers. Here are some empirical analyses on how policy can be undertaken to respond to specific problems in each region.

5.3.1. The impact of price reduction

Based on the analysis of ICT production in Europe, the study found that the chain of the problem concerning the low contribution of ICT sectors was the lack of a technological change effect due to disconnection between ICT sectors and the rest of the economy. The link is described in Figure 5.6 below.

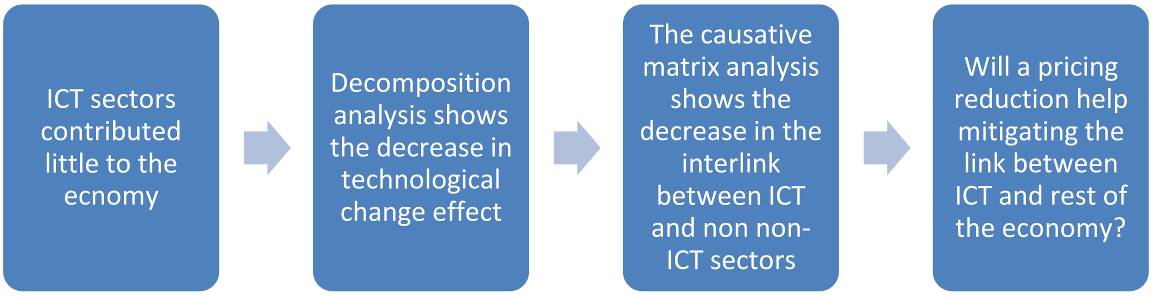


Figure 5.6 Chain of the problem of the decrease in the technological change effect in Europe

The strategy is based on the need to increase inter-relatedness between ICT and the rest of the economy as examined in Paper 3. Hence, the proposed strategy deals with pricing: how will the rest of the sector respond to price changes in the ICT sectors? For this purpose, the sub-sector of media and content is employed as a case. The price of ICT products tends to fall over time, as concluded by many studies (Bagchi, Kirs & Lopez, 2008; Haacker, 2010; Oulton, 2010). Figure 5.7 is examined through the elasticity of GDP with respect to price and calculated based on equation (4.10).

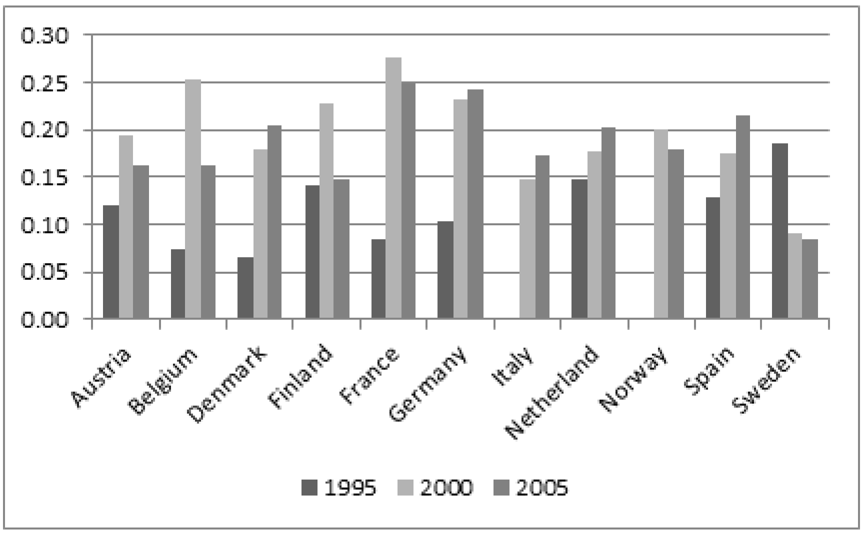


Figure 5.7 Impact of price reduction on GDP (percentage)

From Figure 5.7 it can be concluded that, in general, a reduction in the price of media and content contributes to higher GDP growth. On average, a 1% reduction in price contributed to an increase in the growth of GDP of approximately 0.17% during the last three years' observations. The results vary between countries with France, Germany, Norway and the Netherlands recording higher elasticity than the others.

The next question is the identification of sectors that enjoy the reduction in media and content price. The impact of the price reduction varies between sectors, depending on the intensity of use of the products as intermediate inputs. Thus, the difference in the structure of production and input characteristics leads to a different impact. Tables 5.12, 5.13 and 5.14 show the impact of sectoral GDP as a result of a 1% decrease in the media and content sectors' price.

Table 5.12 Impact on the rest of the economy as a result of a 1% reduction in the media and content sector, 1995 (percentage)[26]

Sector	Elasticity
Manufacture of office machinery and computers	0.62
Computer and related activities	0.45
Publishing, printing and reproduction of recorded media	0.45
Financial intermediation, except insurance and pension funding	0.35
Other business activities	0.34
Post and telecommunications	0.33
Manufacture of coke, refined petroleum products and nuclear fuels	0.32
Air transport	0.27
Manufacture of tobacco products	0.25
Activities auxiliary to financial intermediation	0.25
Renting of machinery and equipment without operator and of personal and household goods	0.22

Table 5.13 Impact on the rest of the economy as a result of a 1% reduction in the media and content sector, 2000 (percentage)

Sector	Elasticity
Publishing, printing and reproduction of recorded media	0.53
Insurance and pension funding, except compulsory social security	0.51
Mining of coal and lignite; extraction of peat	0.47
Other business activities	0.31
Manufacture of office machinery and computers	0.29
Computer and related activities	0.28
Manufacture of tobacco products	0.28
Post and telecommunications	0.27
Manufacture of radio, television and communication equipment and apparatus	0.26
Manufacture of chemicals and chemical products	0.25

[26] The dashed sectors correspond to media and content.

Table 5.14 Impact on the rest of the economy as a result of a 1% reduction in the media and content sector, 2005 (percentage)

Sector	Elasticity
Publishing, printing and reproduction of recorded media	0.55
Post and telecommunications	0.47
Manufacture of radio, television and communication equipment and apparatus	0.42
Other business activities	0.38
Computer and related activities	0.35
Activities auxiliary to financial intermediation	0.27
Extraction of crude petroleum and natural gas; service activities incidental to oil and gas extraction excluding surveying	0.27
Activities of membership organization	0.26
Renting of machinery and equipment without operator and of personal and household goods	0.21
Insurance and pension funding, except compulsory social security	0.21

It can be concluded from Tables 5.12, 5.13 and 5.14 that the price impact of media and content mainly stimulates the sectors that are manufacturing ICT products (radio communication equipment and apparatus) and the financial sector. The media content itself is the sector that enjoys the greatest benefit of price reduction. On average, a 1% reduction in price contributes to an increase in the growth of media and content from approximately 0.4% in 1995 and 2000 and 0.5% in 2005. Thus, the price reduction clearly contributes to a better link of ICT sectors to the economy. At the current moment, however, the link is still limited to the sectors themselves. Thus, it is suggested that the link should be even greater, especially to the service sectors, knowing that these sectors generally have a higher multiplier effect in the European region (Leeuwen & Nijkamp, 2009).

5.3.2. The impact of broadband speed in the European region

This aspect is tightly linked to the fact that even the European region has achieved a decent level of ICT development. The greater challenge concerns the broadband gap. A convincing reason is therefore needed for broadband development to be promoted. The chain of the problem is presented in Figure 5.8

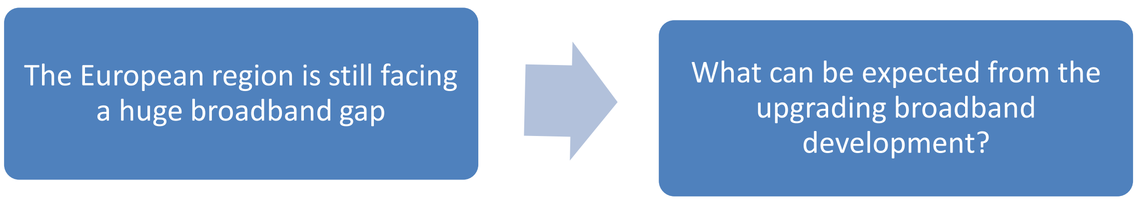


Figure 5.8 Chain of the problem of the need for broadband development

The analysis for responding to this question is based on Paper 4. The first step to be convinced of the importance of broadband development is to look at the correlation between broadband and GDP. With regard to upgrading broadband technology, Figure 5.9 shows the correlation between broadband speed and GDP per capita in the European region.

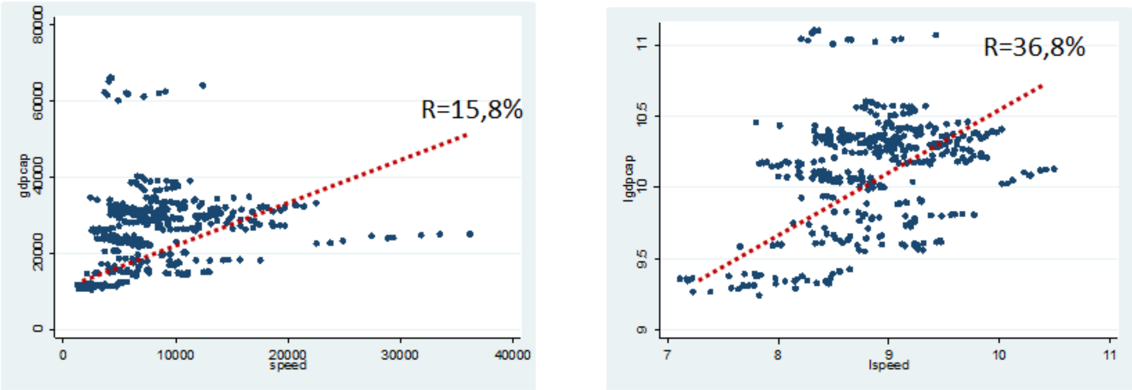


Figure 5.9 Relationship between speed and GDP per capita (left-hand side level, right-hand side growth)

Figure 5.9 shows that there is a positive correlation between the speed of broadband and the GDP per capita. The coefficient of the correlation is even greater when the data are measured at growth level (when the variable is measured at the log instead of the actual value on the right-hand side panel). Furthermore, the econometric testing employing the two-step analysis of fixed effect panel data relating the broadband speed and GDP growth to the growth rate in 2008 is used as the base of the analysis. The result is presented in Table 5.15.

Table 5.15 Impact of broadband speed on GDP per capita

Independent variables	**Coefficient**	
Average GDP growth (2008-2010)	0.577	*
Population density	-0.0441	*
Urban population	-0.0103	**
Labour force growth (%)	0.483	*
Telecom revenue growth (%)	0.0492	*
Population growth (%)	-0.630	**
Average achieved downlink speed	-0.00214	
Average achieved downlink speed squared	0.00142	*

*, ** significant at 1% and 5% critical value respectively

From Table 5.15, the estimated coefficient of broadband speed is not statistically significant, but the square of the variable with the value of 0.0014 is. The coefficient can be translated into an elasticity measurement with elasticity values evaluated at the sample mean. Such an elasticity measurement is of the form 2*coefficient=2*0.00142%=0.00284% ≈0.003% additional GDP mean growth from the base year (2008) by a 1% increase in the speed level. As an example, if the overall economic growth in 2008 is 2%, then the hypothetical *isolated* impact from doubling the speed level on growth would be 2%+0.3%=2.3%.

5.3.3. The need for innovative ICT products in the European region

It has been suggested that the European region needs to be more innovative to serve the ICT customer with more advanced technology products. In this regard, the chain of the problem is presented in the following Figure 5.10.

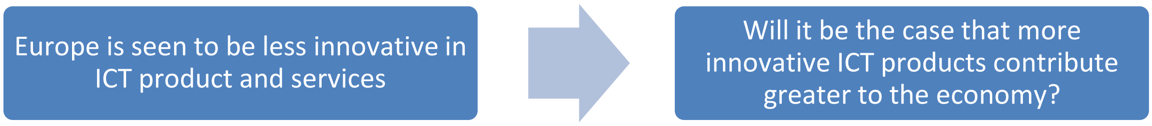


Figure 5.10 Chain of the problem of the lower intensity of ICT innovation in Europe

This analysis is investigated in Paper 11. Based on Figure 5.10, the following analysis answers the question of how more advanced products will contribute to the economy. The Internet Protocol TV (IPTV) is used as the case for this purpose. The product is viewed over a fixed broadband connection (DSL or Fibre to the home, FTTH) with a standard telecommunication set. The services are offered over a closed content distribution network whose common services cover TV broadcasting, stored video on demand (VOD) and the personal video recorder. The IPTV platform can also support a range of digital utility services, such as e-health, e-learning, e-working and home security, and it provides more control and choice for the customer than traditional television.

Table 5.16 compares the multiplier effect of the deployment of IPTV in selected European countries.

Table 5.16 The multiplier effect of IPTV deployment in selected European countries

No	Country	Multiplier
1	Austria	2.840
2	Belgium	1.529
3	Denmark	1.854
4	Finland	1.846
5	France	1.898
6	Germany	1.887
7	Ireland	2.421
8	Italy	2.551
9	The Netherlands	1.977
10	Poland	2.023
12	Spain	1.552
13	Sweden	3.010

From Table 5.16, it can be ascertained that, in general, the multiplier effect of IPTV products is higher than of the ICT sectors due to a higher degree of connection to the rest of the economy. Note that

ICT sectors have a multiplier of about 1.5-1.6 in Europe. The table also shows that Sweden, Austria and Italy have the highest output multiplier of the European countries for this example product.

5.3.4. On the factors affecting the diffusion of ICT in Asia

Previous studies have identified that a common problem of ICT diffusion in developing countries is related to the lack of infrastructure development and other socio-economic factors, namely income, age and education (Nikam, Ganesh & Tamizhchelvan 2004; Bowonder & Boddu 2005; Narayanan, Jain & Bowander 2005; Gamage & Halpin 2007; Ramirez 2007). It will be difficult, however, for the countries to solve all the problems at times. Figure 5.11 accentuates the chain of the problem faced in the diffusion of ICT in Asia, as discussed in Paper 7.

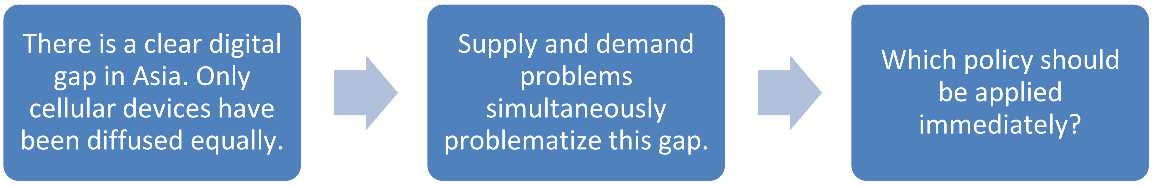


Figure 5.11 Chain of the problem of diffusion of ICT in Asia

Based on Figure 5.11, the following assessment deals with the question: If the policy should be chosen between the demand side and the supply side (e.g. lack of infrastructure development and income level), which one should be considered first to support the diffusion of ICT devices in Asia?

The study takes Indonesia as a case study and investigates the diffusion of mobile broadband access. The analysis contrasts the demand side (income) and supply side (infrastructure that is approached by the urban-rural background of the users). The model employed probit estimation taking three simulations as follows: model 1 generalizes the urban vs. rural classification; model 2 explains the differentiation between Java vs. non-Java, while model 3 observes the difference in terms of cities. The results are presented in Table 5.17.

Table 5.17 Access demand equation estimates

Variables	Model 1	Model 2	Model 3
Male	0.014*	0.013*	0.014*
Higher education	0.089*	0.085*	0.084*
Age1	0.059*	0.059*	0.057*
Age2	0.029*	0.031*	0.028*
Expenditure2	-0.02*	-0.022*	-0.019*
Expenditure3	0.006	-0.004	0.005
Expenditure4	-0.009	-0.011	-0.008
Urban	0.023*		
Java		0.027*	
Jakarta			0.041*
Bandung			0.036***
Surabaya			0.065**
Semarang			0.066*
Medan			-0.003
Makassar			0.002
Balikpapan			-0.003
Batam			-0.005
Heavy Internet users	0.057**	0.043***	0.054**
Married	-0.031*	-0.033*	-0.029*
Own payment	0.019*	0.019*	0.016*
Technician	0.003	-0.007	0.004
Manager	0.137*	0.11*	0.123**

Note: *, **, *** denote the significant at 1%, 5% and 10%.

Table 5.17 shows that the probit estimation yields all the socio-economic characteristics of the respondents (age, gender and education) consistently in explaining the likelihood of a person being a mobile broadband subscriber. The analysis in this study centres on the comparison between the demand side and the supply side. Income (proxied by expenditure), as a demand-side variable, plays a less important role in determining the likelihood of a person being a mobile broadband subscriber. The results show that a middle-lower income respondent has a lower likelihood of being a subscriber, but there is no statistical evidence explaining the conclusion for the higher income user.

In contrast, geographical area plays a more important role based on the model. The urban respondent is 2% more likely to be a mobile broadband subscriber than a rural respondent (Model 1). If the dummy for the geographic location is represented by Java and non-Java, the inference indicates that a respondent living in Java is 2.7% more likely to be a mobile broadband user. Accordingly, if the dummy for the geographical location is represented by cities, the results find that Surabaya, Semarang, Jakarta and Bandung are the spots of the market, while Batam, Medan and Balikpapan are not statistically significant. The results strongly reinforce the need to speed up infrastructure development in countries with a massive disparity like Indonesia.

5.4. Summary of the empirical analysis

Based on the discussion that has been elaborated, Figures 5.12, 5.13 and 5.14 summarize the flow of the analysis of the empirical findings. The figures relate to problem identification of ICT production and diffusion, the deeper root of the problems addressed and the suggested policies corresponding to specific problems.

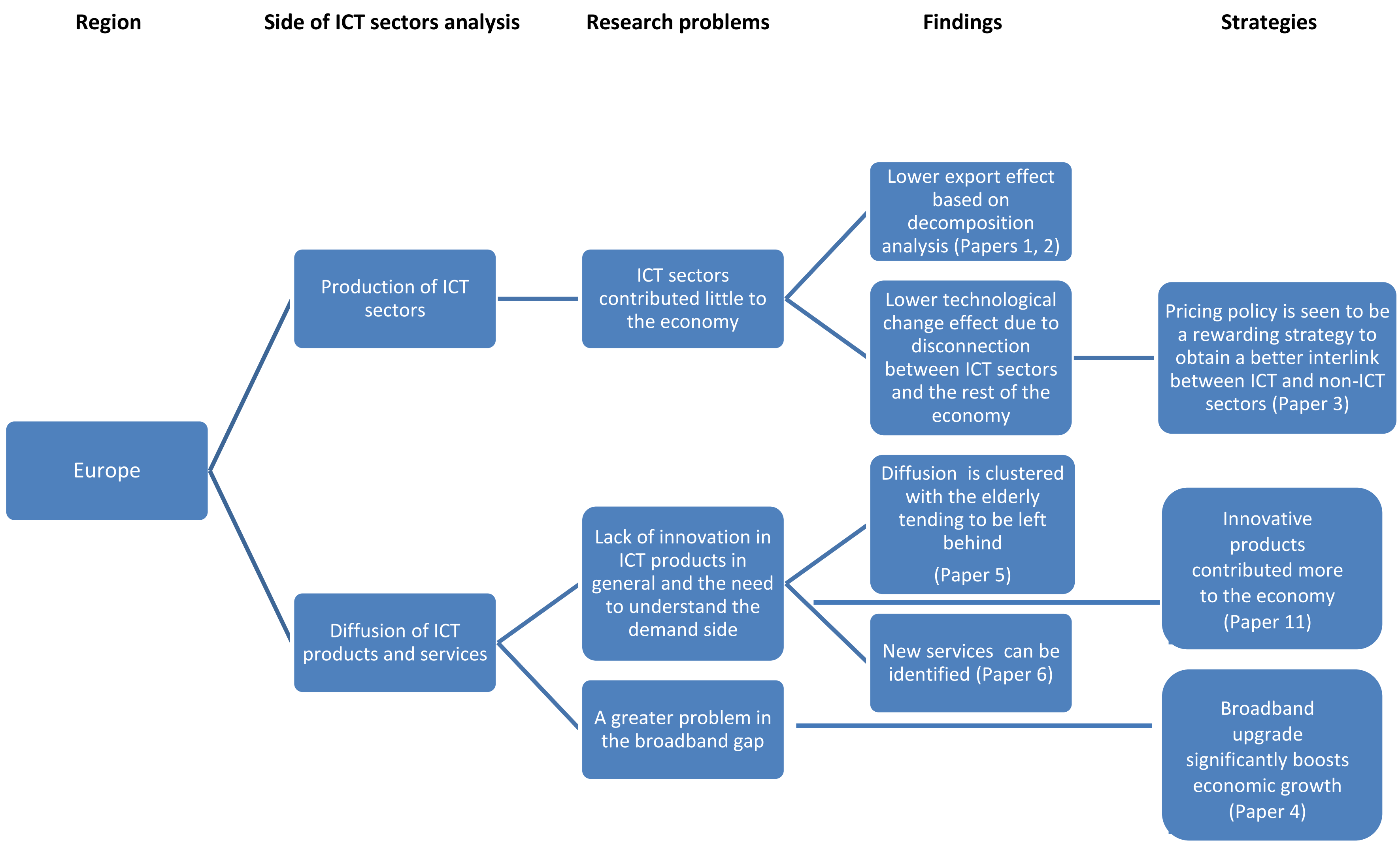


Figure 5.12 Summary analysis of the European region

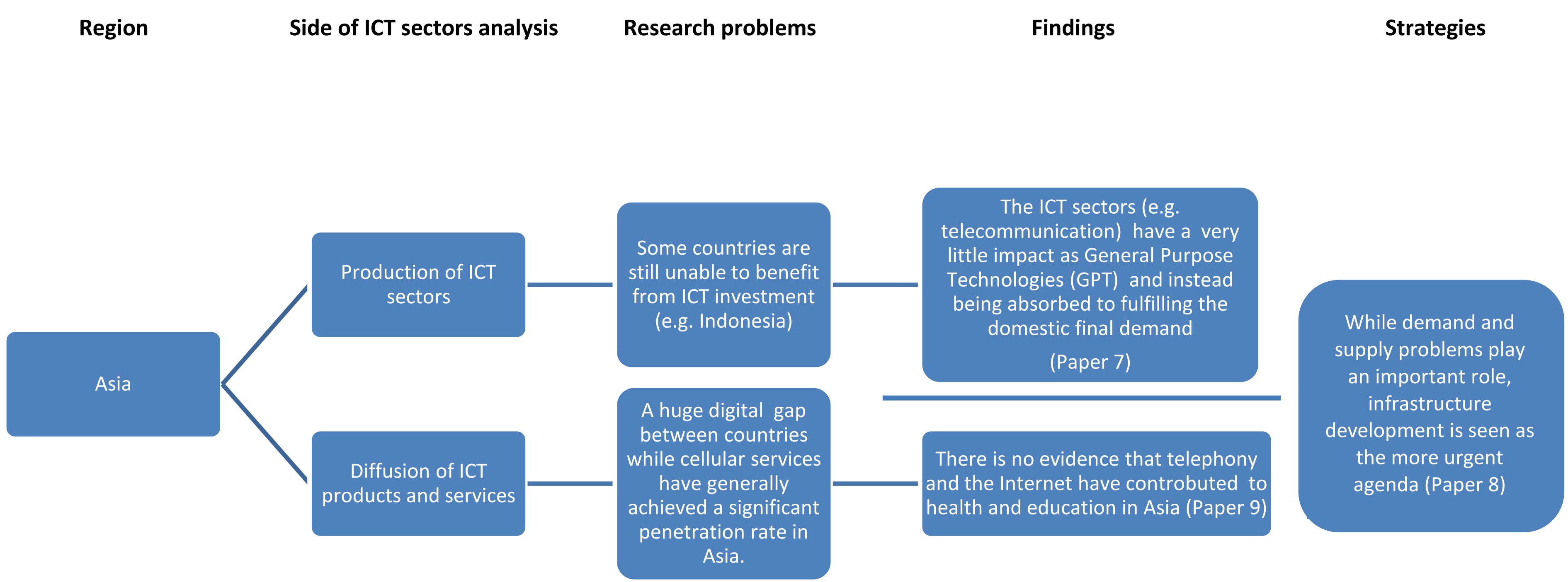


Figure 5.13 Summary analysis of the Asian region

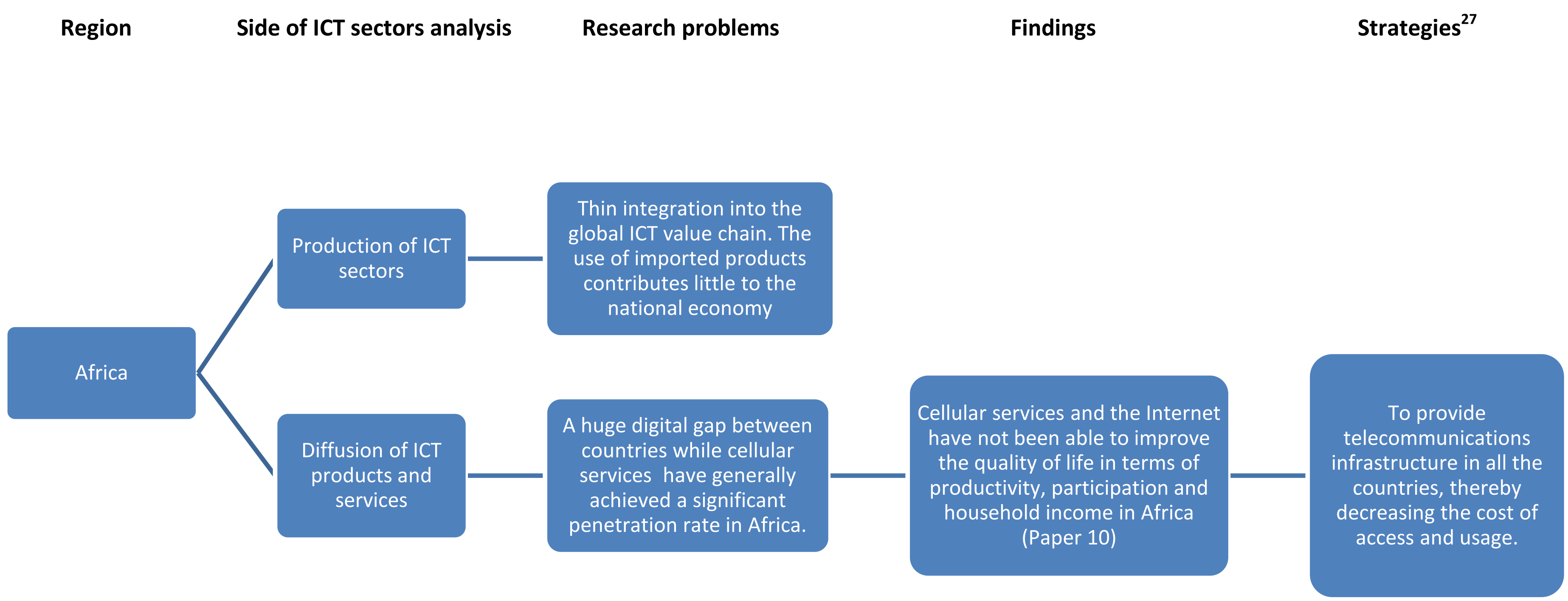


Figure 5.14 Summary analysis of the African region

[27] Unlike the case in the European and Asian regions, the strategy derived in Africa is not based on the empirical analysis conducted by the author; this issue was investigated by previous studies, as discussed in Paper 10.

Chapter 6 Summary of the study

This section presents a summary of the study by first wrapping up the conclusion from the previous chapters and defining to what extent the study has been able to fill the gap of the current literature. The later part of the section explains some limitations of the current analysis and a possible direction for future studies.

6.1. Conclusion

6.1.1. On the European region

From the ICT production analysis, the dissertation's finding was similar to that of van Ark, O'Mahony and Timmer (2008), and Barrios and Burgelman (2008) that the ICT sectors in general contributed less to the European economy. However, the dissertation adds up the problems identified by previous studies, in which Ark, O'Mahony and Timmer (2008) concluded the lower multifactor productivity, and Barrios and Burgelman (2008) found the lower intensity in ICT investment to be the source of the problem.

The dissertation first identified that ICT sectors have a lower multiplier effect in the European region. Further analysis emphasizes two problems that have not yet been addressed by previous studies concerning the export effect and the technological change effect. In this view, the comparative advantage of ICT products exported to the rest of the world has been declining, whereas the lesser technological change effect contributed from the sector to the rest of the economy is attributable to the disconnection between the ICT sectors and the other sectors. The conclusion can be drawn at country analysis and sector level. The country analysis found that the large economies (e.g. France, Germany and Spain) fall into the group in which ICT has a lower connection to the other sectors. Likewise, the sector analysis concludes that the majority of the ICT sectors, including telecommunication, are also classified as endogenized sectors; hence, they contribute less to the economy and have less feedback from the other sectors.

On diffusion, the study found a similar conclusion to Vicente and Lopez (2008), pointing out that the ICT diffusion needs to include a specific group (the elderly), as the aim is to increase digital inclusion. It has also been found that particular devices should be developed in the future to respond to the needs and demands of the users (e.g. based on a case study in Sweden, mobile map, mobile concierge and mobile customize information on mobile telephony services).

This study offers three possible strategies for dealing with the problems in ICT production and diffusion in the European region:

First, on ICT production, the study found that continual price reductions in ICT will mitigate a better link between the ICT sectors and the other sectors. A reduction in the price of ICT contributes to higher GDP growth, in which France, Germany, Norway and the Netherlands recorded a higher elasticity than the others. The price reduction also enables a tighter connection between ICT and other sectors, especially the service sector, which was generally identified as having a greater multiplier effect in Europe.

Second, the region should be more innovative when developing ICT products and services. Taking the case of IPTV, the study found that innovative products generate a greater multiplier effect for the economy. As the market becomes more innovative, so it becomes more likely that the product offered in the market also becomes cheaper, which supports point (1) above.

Third, the analysis of the broadband sector concluded that upgrading broadband technology, which corresponds to increasing the speed level, signifies economic growth at a substantial level. Driven by the fact that the region still faces a huge broadband gap, the broadband development aims to enhance broadband capacity, thus becoming an urgent agenda.

6.1.2. On the Asian and African regions

The Asian and African regions face similar problems concerning the huge digital divide across countries, though some NIEs in the East Asian region are at the front of ICT production and diffusion in the world (let alone compared with Africa). On questioning why some countries in Asia are not yet able to benefit from the ICT investment, the case study in Indonesia found that the greater portion of the output from the ICT sectors is dedicated to serving the domestic final demand. Consequently, the sectors play an insignificant role as GPT sectors. The phenomenon has been even more visible in recent times when the country was undergoing the massive development of the cellular era. A further analysis on the pattern of usage is needed to strengthen this finding. A study in Africa (Kenya and Ethiopia) also found the same phenomenon, which might support the finding in Indonesia. In 1980, when telephony was mainly installed in the forms of fixed line and public phones, the main usage by telephone subscribers was aimed at business purposes (Saunders et al., 1983). However, a decade later, when cellular devices had evolved, the use of cellular telephony had shifted and become unrelated to business activities (Samuel, Shah, & Hadingham, 2005; Donner, 2005; Diga, 2007; Rettie, 2008; Hahn & Kibora, 2008).

On the relationship between ICT development and socio-economic variables, the study concludes the same findings for the Asian and African regions. Employing cointegration analysis for the data from the 1980s to the 2000s, there is no evidence of the existence of a long-run relationship between the ICT devices with education and health in Asia. The analysis in Africa is conducted to see whether the impact of ICT adoption on cellular devices and the Internet has led to a better quality of life in terms of household income, participation and productivity, employing the survey data in 14 countries. The study concludes similar results to those in Asia for which there is no impact of ICT diffusion on these quality of life variables.

Moreover, the dissertation recommends a policy in relation to closing the digital gap in developing countries. Taking Indonesia as a case study, the study found that the availability of infrastructure plays an important role in the current diffusion, suggesting a need for immediate infrastructure provision throughout the country. Such policies may be adopted by other developing countries facing a huge disparity between urban-rural and geographical dispersion. The finding is consistent with Saunders et al. (1983) in Africa. Given the lower basis at the initial stage, basic ICT (e.g. telephony) in developing countries can grow at relatively high rates, with the common phenomenon in the region not being the lack of demand but limited capacity from the supply side.

6.2. The contributions of the dissertation

The following section presents the contributions drawn from the dissertation. The contributions mainly relate to the novelties of the appended papers compared with existing studies in terms of the methodologies applied to investigate the problem and the empirical findings.

6.2.1. Contribution in terms of methodologies

European region

The study in the European region (Papers 1, 2 and 3) adopts previous studies conducted by Roy et al. (2002), and Heng and Tangavelu (2006) that investigate the impact of ICT on the information economy. In this dissertation, the definitions of ICT sectors follow those of the OECD (2009), enabling a more careful classification of ICT sectors. In terms of the definition of ICT sectors, this study is similar to van Ark, O'Mahony and Timmer (2008) but provides a more detailed analysis of the selection of ICT sectors. Moreover, the study transforms a complete translation of the OECD's ICT sectors classification (OECD, 2009) to the IO sectors. The analysis also covers the media and content sector, including education. For this reason, Katz (Katz, R., personal communication, email, February 1, 2010) believed that the study is critical and that it has not yet been widely explored.

In view of the coverage of the study, previous studies on the economic impact of the ICT sectors were mostly conducted in the country case study, given the complexities and the compatibility problem between IO tables (for instance in broadband analysis). This study continues the coverage by Gould and Ruffin (1993), Ark et al. (2008) and Eichengreen (2008) of 12 selected European countries that are believed to have been experiencing an advanced level of technological development.

The other appended paper (Paper 4) on the impact of broadband speed in the European region is one of the first studies to strive to quantify this issue, as many studies focus on investigating the impact of the penetration rate. The speed data for this study are gathered with careful examination extracted from the daily basis data.

The Asian and African regions

An appended paper on Asia (Paper 8) tries to cut the never-ending chicken and egg problem to foster ICT development in typical least developing countries. It is generally understood that the development of the region still faces a huge digital divide due to geographic dispersion and socio-demographic factors, for instance, income, education, geographic dispersion, etc. (Nikam, Ganesh & Tamizhchelvan, 2004; Bowonder & Boddu 2005; Malekian, et al., 2011). The study tries to show that infrastructure provision should be a prerequisite factor for boosting further economic development.

Moreover, only a few studies investigate the relationship between ICT development and socio-economic variables and quality of life. Filling up this niche, Papers 9 and 10 approach this issue from a more quantitative basis, even though the framework and the measurement of quality of life could be improved for the next study.

6.2.2. Contribution in terms of empirical results

The contribution is presented based on what the existing literature has found and how the dissertation fills the gap of investigating the problem of ICT production and diffusion in the European, Asian and African regions. Such contributions take the form of focusing the current problem to figure out the roots of problems, and some polices are also derived to deal with the existing challenges of each region. Table 6.1 presents the analysis.

Table 6.1 Existing studies and contribution of the dissertation

Region	Production		Diffusion	
	Existing studies	Contribution of dissertation	Existing studies	Contribution of dissertation
Europe	The ICT sectors contributed little to the overall productivity (compared with the United States) due to the late momentum, smaller investment and lower multifactor productivity.	The main problem is not the investment itself but it is driven by two main points: (i) the vanishing export effect and (ii) the decline in the technological change effect from the ICT sectors to the rest of the economy. The lack of the technological change effect is due to the endogeneity of the ICT sectors, which means that the inter-relatedness between the sector and the rest of the economy has diminished.	Demand-side policy is generally left behind for policy consideration. The digital divide between countries exists, especially for broadband. The European region generally lacks innovative products.	The study finds that future products should be developed based on demand estimation. The broadband development will clearly boost economic growth with a substantial impact. Thus broadband policy is an urgent agenda for the region. Innovative products are needed as they are believed to contribute more to the economy than those of the conventional ICT sectors.
Asia	While ICT production is generally only limited and clustered in some NIE countries, it has been found that in some Asian developing countries (e.g. Indonesia), ICT investment contributes little to the economy. .	The reason might be that the majority of ICT sector output is aimed at fulfilling the domestic final demand, with a small portion for the technological change effect. Thus, the impact to generate economic growth, taking the role of GPT, is limited or non-existing.	A common problem in developing countries is that the socio-economic progress is still very slow despite the progressive achievement of ICT diffusion.	The current face of ICT diffusion may be overwhelming. There is no indication that ICT development has actually been able to improve socio-economic development, namely health and education.
			The diffusion of ICT devices faces a lack of infrastructure investment, geographical problems and other socio-economic indicators.	While it is generally understood that developing countries will not be able to solve all problems at times, the study found that comparing the demand and supply side

				resulted in an immediate agenda for infrastructure provision.
Africa			Like Asia, there are common problems in developing countries in Africa regarding the slowness of socio-economic progress despite the progressive achievement of ICT diffusion, especially in mobile telephony.	The finding shows that ICT diffusion at the current state fails to improve the quality of life in terms of the household income, participation and productivity.

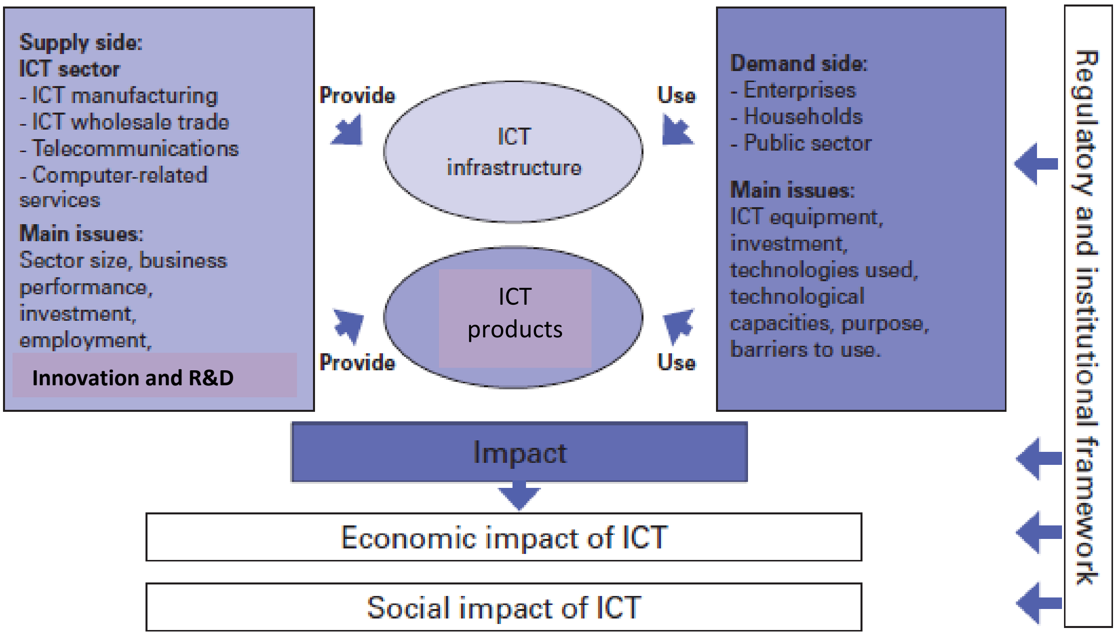
6.3. Future directions

As for the future direction, the most obvious aspect is related to the number of studies, which differs between regions. Setting the aims at enabling a better comparison, the studies in Asia and, particularly, Africa should be developed with more updates of data and methodology. The analysis in the European region should also be updated with the newer publication of the IO table, or more dynamic methodology should allow the impact of price changes (as found in the Computable General Equilibrium) to be captured. Table 6.2 shows the future direction of the study.

Table 6.2 Future direction of the study

Region	Possible future direction
Europe	This study puts more emphasis on the export effect and the technological change effect of the ICT sectors. It is important, however, to investigate also other issues of decomposition factors: the domestic demand as the intra-regional activities within the European region is huge. The ICT sector classification is still too wide. The development of ICT is now being supported more by a variety of products and services. Nevertheless, the 59 IO sectors are not appropriate to grasp a more detailed elaboration. Thus, a single country study, applying a wide range of IO sectors, will contribute even more to a practical analysis. As suggested by Koski, Rouvinen and Yla-Anttila (2002), the activities of ICT production are borderless within the European region, which implies that policies focusing on national interest will be insufficient and instead more local and/or regional policies are needed to promote ICT. Future studies must focus the investigation by looking at particular industries/sectors.
Asia	From ICT production, the investigation can be expanded to other countries though not Indonesia. Future studies can be directed at answering the question of how to transfer the success story in NIE countries to other developing economies and which factors are considered important drivers in boosting ICT production.
Africa	The dissertation and appended papers do not currently address the ICT production (or manufacturing or investment) in the African region, claiming that the region has little integration into the global value chain and that the ongoing issue still touches on the digital divide/diffusion side. Other studies explain the emergence of ICT production in Africa (Chowdhury, 2006; Kabanda, 2008; Bollou & Ngwenyama, 2008; Bell & Juma, 2008). As shown in the current report by Davies (2010), the emergence of ICT manufacturing in Africa is currently driven by China's manufacturing expansion. Future studies should look more thoroughly at this issue.

As addressed in Chapter 1, the alternative framework using a demand-supply analysis to evaluate the development of the ICT sector could be applied to future study. The framework is presented in Figure 6.1.



Source: OECD (2005), UNCTAD (2009)

Figure 6.1 Supply and demand framework for investigating ICT development

Figure 6.1 describes the supply and demand framework as an analysis inter-related with the impact assessment (in terms of both economic and social benefit) as well as the institutional framework. The framework is seen as a comprehensive tool to analyse ICT development. Supply-side data comprise statistics on manufacturing and service industries that supply ICT infrastructure, goods and services. Measurements from the demand side address access to and use of ICT by businesses, households and government organizations. With strict definition and operationalization, a supply and demand framework based on a case study in a particular country analysis can be investigated, especially when the country avails the data needed for such an investigation.

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