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The globalization and stagnation of the ICT sectors in European countries: An input-output analysis

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ABSTRACT

Recent studies of European countries indicate that the contribution of the ICT sectors to the regional economy is weakening and slowing economic growth. The present study investigates the contribution of the ICT sectors to economic performance in the European economies using Input–Output (IO) methodology. The results indicate that: (1) the multiplier effect of the ICT sectors on the rest of the economy declined significantly during the period 2000–2005 compared with 1995–2000; and (2) the decline in the output of the ICT sectors can be attributed to the loss of export advantages and technical change gains in the sectors. The results show an inability of the sectors to grasp the international market, most likely a consequence of the lack of anticipation of more rapid innovation in emerging countries.

1. Introduction

Economists have long recognized that technological change is one of the most important forces driving economic growth, together with human capital and knowledge accumulation. This conclusion can be found, for instance, in Romer (1986) and Maddison (1991). Romer (1986) incorporated a knowledge factor as an input in the production function and found that, instead of generating a traditional diminishing-returns on production function, human capital supports increasing return to scale (as also found in Milgrom, Quaian, & Robert, 1991). Following this study, Romer (1990) added that the additional portion of human capital constituted by research and development (R&D) is also an important determinant accelerating the rate of growth. This conclusion was also found in the study by Lucas (1988) that explained the role of human capital to sustaining the level of economic growth in the long run. The role of human capital and an educated population are, thus, concluded as crucial factors of economic growth, for instance in those of Barro (1991), Mankiw, Romer, and Weil (1992), and Levine and Renelt (1992).

The importance of technology became more visible in many studies showing the link between technology, innovations and R&D. Steindel and Stiroh (2001) concluded that a major source of the better aggregate performance has been driven by high technology sectors. Therefore, technology is no longer seen as a traditional investment, but as Bresnahan and Trajtenberg (1995) assert, the role of technology has become more important as the catalyst in the creation 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 where technological development in terms of R&D plays distinctive factor. Moreover, the importance of technology is also supported by the conception of the general purpose technology (GPT). This concept is characterized by potential for pervasive use of technology in a wide range of sectors; hence, a technological dynamism enables generalized productivity gains transferred to the rest of economy (Rosenberg, 1982).

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Table 1
Contribution to growth of real output in the market economy (%).
Source: van Ark et al. (2008).

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	Labor productivity (4)+(5) +(8)	2.4	1.5
	Composition		
4	Labor 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 labor productivity (4)+(6)+(8)	1.6	1.1

An analysis of the impacts of technology necessarily has to take Information and Communication Technology (ICT) sectors into account. The OECD (2009, p. 14) emphasizes that ICTs are one class of GPT that can be used for a broad range of economic and everyday activities. Consequently, new modes of individual behavior have emerged, including new or modified means of personal communication and interaction. In line with this argument, Kramer, Jenkins, and Katz (2007) also stress that continual reporting on (information) technology has helped raise awareness of the importance of ICT diffusion to overall competitiveness. Thus, they also refer to the role of the ICT sectors in explaining the technology sector.

IPTS (2011) delivered an extensive report on the performance of ICT sectors in the European economy. It first identified and classified the ICT sectors into two groups: ICT manufacturing and services.[1] Based on this classification, IPTS reported that in 2008, the value added by the ICT sectors was 4.7% of GDP (or equivalent to 574 billion euros). With 8.2 million jobs, the sector generated 3.6% of total employment. Job creation was strongly oriented towards ICT services, which accounted for 6.2 million jobs. The ICT sectors also ranked high by contributing 25% of the total business expenditure on R&D.

Despite this high contribution, IPTS (2011) found that the European region is now lagging behind the US and other emerging countries. With contribution of the ICT sectors to GDP of approximately 4.7% in 2008, the share in European region is smaller than that in China (6.6%), Japan (6.9%), Korea (7.2%) and Taiwan (10.5%). This also reflects that, in general, the output of ICT manufacturing in Asia is higher than that in the EU. The R&D intensity (measured by the ratio of R&D expenditure to sectoral value added) in Europe is also lower than that in the US and emerging countries. The proportion of R&D intensity of 6.2% recorded in the EU are lower than comparable numbers for the US (11.2%), Japan (12.8%), Korea (16.5%), and Taiwan (12.3%).

A study by van Ark, O'Mahony, and Timmer (2008) shows that the contribution of the ICT sectors has fell between the 1980s and the 2000s, as shown in Table 1.

Table 1 reveals that although the European countries enjoyed a slightly higher contribution of ICT capital during the period 1995–2004 than in the previous 15-year period (0.5% compared to 0.4%), there was a considerable decline in the contribution of knowledge economy from 1.6% to 1.1% between the first and the second period.[2] This decline was driven by three factors; labor composition (4), capital deepening (5) and multifactor productivity (8). While the labor composition and capital deepening just slightly decreased (from 0.3% to 0.2% and 1.2% to 1% respectively), the multifactor productivity fell considerably from 0.9% to 0.3%. The finding on multifactor productivity, according to van Ark et al. (2008), reflects the overall inefficiency of the production process.

In addition, a comparative study of selected European countries shows that the contribution of the ICT sectors to economic growth varies between countries, as shown in Table 2.

Finland showed the highest contribution from the ICT sectors as shown in Table 2. The contribution of ICT sectors to the growth of output in Finland is even higher than that of goods and services. In relation to this, Finland has recorded a massive structural change considering the country was previously one of the least ICT-specialized countries back in the 1990s. Jalava (2002) explains the phenomenon in Finland happened as the impact of a positive reallocation of labor, which was primarily a consequence of an increase in the employment share of ICT production. The Netherlands and Germany are also considered to have a fairly high contribution from the ICT sectors although the growth rate is lower than for goods.

van Ark et al. (2008) also conducted a comparative analysis of the productivity rates in the US and Europe as shown in Table 3.

[1] ICT manufacturing consists of IT equipment, IT components, telecom and multimedia equipment, telecom equipment (e.g., network equipment, mobile phones), multimedia equipment (e.g., TVs, DVD players, and video game consoles) and measurement instruments, whereas ICT Services consist of telecom services (e.g., fixed line, mobile telecommunications) and computer services and software (e.g., consultancy, software, the Internet).

[2] van Ark et al. (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.

Table 2
Contribution to the growth of real output in the market economy, 1995–2004 (%).
Source: van Ark et al. (2008).

Countries	Market economy	ICT production	Goods production	Market services
Austria	2.2	0.3	1.7	0.3
Belgium	1.7	0.3	1.0	0.5
Denmark	1.4	0.3	0.8	0.3
Finland	3.3	1.6	1.3	0.4
France	2.0	0.5	1.0	0.6
Germany	1.6	0.5	0.9	0.2
Italy	0.5	0.3	0.3	0.1
The Netherlands	2.0	0.4	0.6	1.1
Spain	0.2	0.1	0.1	0.1
The European Union	1.5	0.5	0.8	0.5

Table 3
Average annual growth rate of GDP, GDP per capita and GDP per hour worked, EU-15 and United States, 1950–2006 (%).
Source: van Ark et al. (2008).

Period/countries	Growth in		
	GDP	GDP per capita	GDP per hour work
1950–1973			
EU-15	5.5	4.7	5.3
US	3.9	2.4	2.5
1973–1995			
EU-15	2	1.7	2.4
US	2.8	1.8	1.2
1995–2006			
EU-15	2.3	2.1	1.5
US	3.2	2.2	1.3

Table 3 depicts a slowdown in productivity and contribution from the ICT sectors to economic growth in the European countries compared with the US. The study argued that this phenomenon is due to the slower emergence of the knowledge economy, driven by lower growth contributions from investment in the ICT sectors in Europe. Additionally, the relatively small share of technology-producing industries and slower multifactor productivity growth also explain this finding as also found in Table 1.

The remainder of the paper is organized as follows. Section 2 expresses the research questions of the study. The theory on innovation in the ICT sector is briefly explored in Section 3 and the data and methodology are discussed in Section 4. Results are presented in Section 5 and Section 6 offers a conclusion.

2. Research questions

Building on this earlier work but employing a different methodological framework, this study attempts to answer the following two research questions concerning the decreasing contribution of the ICT sectors:

RQ1. What was the contribution of the ICT sectors to the output of the European economy in the period 1995–2005?

This question is investigated by calculating the output multiplier to examine how the change in the ICT sectors' final demand contributed 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 in the European economy.

RQ2. What are the determinants of changes in the output of the ICT sectors in the European economy?

The second research question is designed to reflect the need to observe the factors that affect the change in output by the ICT sectors. The basic model of equilibrium demand and supply implies that the change in output for a particular product comprises of four sources: the domestic final demand effect, export effect, import substitution effect and technological change effect. This research question aims to identify the most important decomposition factor and discover which decomposition factors should be considered further. The second research question is becoming increasingly important as it aims to provide an answer to the impact of globalization on the ICT sectors' performance in the European countries as well as understand the strategic position of the ICT economy in the region compared with other emerging nations in the world.[3]

[3] This paper focuses on one decomposition factor concerning the export effect. The study by Rohman (2012) investigates the analysis on technological change effect especially on investigating the lower inter-relatedness between ICT and non-ICT sectors in the European region.

Previous studies that have employed IO methodology focused on the economic impact of ICT sectors, in particular broadband (Katz, 2009; Crandall, Jackson, & Singer, 2003; Liebenau, Atkinson, Karrberg, Castro, & Ezell, 2009). For instance, Katz and Suter (2009) assert that expenditure on providing broadband services in the US creates employment as a result of multiplier effect. The study estimates that, due to the employment multiplier, the provision of broadband services created 32,000 jobs per year over the 4 years of the project. The Strategic Network Group (2003) also estimates that the impact of the investment in fiber optic networks can be investigated through the effect of the creation of new jobs, expansion of commercial facilities, increased revenues and decreased costs.

This paper goes beyond the analysis of economic impact of ICTs and instead scrutinizes the reasons behind it. This is done by conduction a decomposition analysis and investigating the interrelatedness between sectors. The study also provides a strict definition of ICT sectors using the OECD classification (2009).[4] Moreover, the study is conducted at country level, thus enabling a comparative analysis between nations.

3. Globalization of innovation

The ICT sectors and innovation are tightly linked, as innovation is the catalyst for growth of the sector. In the telecommunications sector, Nadiri and Nandi (1999) demonstrated how the rate of technological change is the main determinant of productivity growth in the telecommunications industry in the US. The authors found that 50% of total factor productivity (TFP) growth during the entire 1935–1987 period was influenced by technological innovation. Not only will innovation drive the ICT sector itself, but innovation in the ICT sectors percolates through other sectors. For example, in telecommunications, innovation happens at three interconnected layers: the physical layer (networks and devices), the logical layer (protocols and middleware), and the content, service and application layer. As applications and services are used widely, the impact of innovation in ICT spreads to the whole economy (Bauer & Chattopadhyay, 2010).

Archibugi and Iammarino (2002) explain the fundamental analysis of the concept of globalization, dealing with innovation that is conceived as the zip between two fundamental phenomena of modern economies: increased international integration of economic activities and rising importance of knowledge in economic processes. As a result of globalization, the expansion of global forces has remained circumscribed to the most developed part of the world but with increasing polarization of economic and innovative activities in the emerging economies.

There is an evidence that, given the current fierce competition at industry level, the innovative firms are only able to prolong their dominance in the market if they can decentralize R&D abroad. The influence of international R&D activities on new product development and firm novelties is about one-third greater than the effect of domestic R&D activities, suggesting a need to increase the operational linkages to a more international market scope (Peters & Schmiele, 2011). Another study by Ernst (2002) also stresses the importance of international linkage in R&D activities. The study explains that openness to foreign ideas and knowledge, and a capacity to absorb these and blend them with existing capabilities are a requirement of successful innovative sector development. In this regard, the EU should anticipate increasing global competition from newly industrialized countries such as Taiwan, South Korea and Singapore, as well as countries that are rapidly catching up such as China and India (Asheim & Coenen, 2006).

Based on this related research, this paper tries to link the performance of ICT sectors with globalization, in particular to see whether the structural change of output in ICT sectors can be attributed to or influenced by globalization. This indicator is gathered by looking at two aspects of the decomposition factor: the export effect and the import substitution effect (Tables 4 and 5).

4. Methodology of study

The input–output (IO) table depicts the transaction flow across sectors, where each sector produces a certain output and, at the same time, consumes input from another sectors. 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 reflects the flow of intermediate output and intermediate input.

The advantage of the IO method is its ability to capture direct and indirect impacts as well as to assess the impacts at both macro- and meso-level (industry level). An IO table represents the relationship between firm and industry data. The intermediate transactions that are contained in quadrant I of an IO table are based on data gathered from industry surveys (Yan, 1968, pp. 59–60; the United Nations, 1999, p. 3; Miller & Blair, 2009, p. 73). Furthermore, the relationship between sectoral and macro-data is given by the fact that the primary inputs (the summation of wages, salary and operating surpluses) in quadrant II of the IO table also add-up to the measurement of Gross Domestic Product (GDP) from income approach.

[4] Two other studies cited in this paper adopt different category of IT or ICT sector; Roy, Das, and Chakraborty (2002) delimit the Information and Technology (IT) sectors as office computing, communication equipment, electronics equipment, communication, and education and research, whereas Heng and Thangavelu (2006) refer to publishing, computer and computer peripherals, electronics and communication product, communications, information and technology services, and education as information sectors.

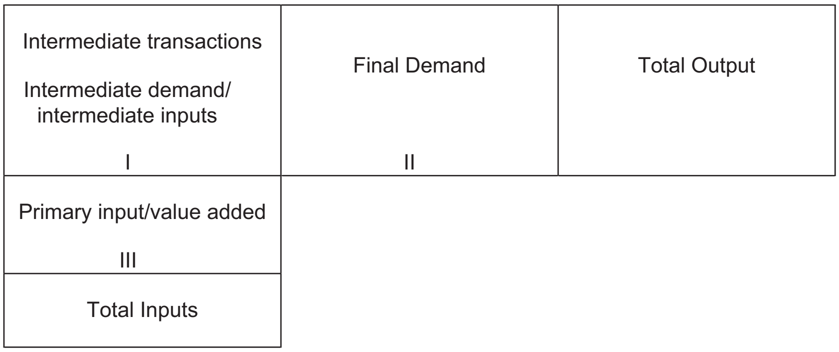

Fig. 1. Input–output (IO) table.

The representation of the IO table and its quadrants is shown in Fig. 1.

To operationalize the method, assume that the transaction flow in the IO table explained by a system Eq. (1) below where there are four sectors in the economy:

$$\begin{aligned} \boldsymbol{x}_{11}+\boldsymbol{x}_{12}+\boldsymbol{x}_{13}+\boldsymbol{x}_{14}+\boldsymbol{c}_1&=\boldsymbol{x}_1\\ \boldsymbol{x}_{21}+\boldsymbol{x}_{22}+\boldsymbol{x}_{23}+\boldsymbol{x}_{24}+\boldsymbol{c}_2&=\boldsymbol{x}_2\\ \boldsymbol{x}_{31}+\boldsymbol{x}_{32}+\boldsymbol{x}_{33}+\boldsymbol{x}_{34}+\boldsymbol{c}_3&=\boldsymbol{x}_3\\ \boldsymbol{x}_{41}+\boldsymbol{x}_{42}+\boldsymbol{x}_{43}+\boldsymbol{x}_{44}+\boldsymbol{c}_4&=\boldsymbol{x}_4 \end{aligned} \tag{1}$$

Eq. (1) represents the economy consisting of four sectors (1–4), each sector produces and consumes output from their own and other sectors. From Eq. (1), $\boldsymbol{x_{ij}}$ denotes the output from sector i used by sector j as an intermediate input (or, in other words, it measures the input from sector i used for further production processes in sector j). In the IO table, these values are located in quadrant I. Moreover, $\boldsymbol{c_i}$ ($i=1,\ldots,4$) refers to the total final demand of sector i, whereas $\boldsymbol{x_i}$ refers to the total output of sector i.

Introducing the matrix notation, Eq. (1) can be modified to obtain the following matrix column:

$$\boldsymbol{x}=\begin{pmatrix}\boldsymbol{x}_1\\ \vdots\\ \boldsymbol{x}_4\end{pmatrix}; \quad \boldsymbol{c}=\begin{pmatrix}\boldsymbol{c}_1\\ \vdots\\ \boldsymbol{c}_4\end{pmatrix} \tag{2}$$

From Eq. (2), x denotes the column matrix of output and c the column matrix of final demand. The following matrices, $\boldsymbol{I}$ and A, are the identity matrix and technology matrix respectively and they are used to further measure the multiplier.

$$\boldsymbol{I}=\begin{pmatrix}1&0&0&0\\0&1&0&0\\0&0&1&0\\0&0&0&1\end{pmatrix}; \quad \boldsymbol{A}=\begin{bmatrix}\boldsymbol{a}_{11}&\cdots&\boldsymbol{a}_{14}\\ \vdots&\ddots&\vdots\\ \boldsymbol{a}_{41}&\cdots&\boldsymbol{a}_{44}\end{bmatrix} \tag{3}$$

The left-hand side of Eq. (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, 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.

Next, the equilibrium of the equation for demand and supply in Eq. (1) can also be written as follows:

$$\boldsymbol{Ax}+\boldsymbol{c}=\boldsymbol{x} \tag{4}$$

where the output is denoted as:

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

The first row of Eq. (4) is the general form of Eq. (1). The multiplier is defined as the inverse Leontief matrix, $(\boldsymbol{I}-\boldsymbol{A})^{-1}$. It measures the change in equilibrium output of the aggregate economy caused by a unit change in the final demand of the industry sector. Throughout this study, the IO table has been transformed into constant terms in order to be appropriate for growth measurement. Therefore, since the IO is calculated on the basis of current prices, the GDP deflator is used to change all the values into constant terms.[5]

[5] The more thorough estimation on deflating the IO table is explained, for instance, by Celasun (1984) in the case of Turkish structural change of economy. The same method using the sectoral producer price index and import price index can be seen in Zakariah and Ahmad (1999) on the Malaysian economy. This study only uses the GDP deflator to obtain the constant value of IO table. A similar method can be found in Akita (1991).

4.1. Multiplier analysis

Referring back to Eq. (4), the multiplier measures how total output changes as a result of the change in the final demand. The size of multiplier coefficient largely depends on the inter-relatedness between a particular sector to the rest of economy as shown in the Leontief matrix. In the other words, if the sector plays important role for the whole economic activities, there will be a stronger interaction between the sector and the rest of other sectors. For instance, if sector 4 plays a central role in the economy, the technology matrix (A) consists of the element such a way that each element of a_{41}, a_{42} and a_{43} is higher than that of other elements (e.g. a_{21} and a_{31}). In this regards, sector 4 will have the highest multiplier coefficient compared with sectors 1, 2 and 3.

This study corresponds to the method of simple multiplier measurement and the domestic transaction model. Hence, in calculating the multiplier, only goods and services produced domestically affect the value of the multiplier. Furthermore, the multiplier uses the open IO table instead of the closed one. A closed IO consists of all sectors within the economy and assumes that consumption is endogenous and thus, the consumption is also included into Leontief matrix. Contrary to this, an open IO only utilizes the interrelatedness of production process leaving consumption exogenous. Grady and Muller (1988) show that the use of a closed IO table usually yields exaggerated estimates of the impact.

It has to be considered, though, that the application of the IO methodology in this study has to follow some strict assumptions. Hastings and Brucker (1993) summarized these assumptions: (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, 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 a change in the final demand affects 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. These assumptions do not limit the ability of the method to investigate the impact analysis of the economy, however (Taylor, Winter, Alward, & Siverts, 1992; Miller & Blair, 2009, p. 13).

4.2. Decomposition analysis

Skolka (1989) explains that decomposition analysis can be defined as the method of distinguishing major shifts in the economy by means of comparative static changes in key sets of parameters. Blomqvist (1990) cited Fisher (1939) and Clark (1940), among others, who were the first to introduce the concepts of decomposition analysis. They distinguished primary, secondary and tertiary sectors, a classification which is still widely used today. Chenery (1960) first employed the method to identify the source of structural change and industrial growth. One of the conclusions of the mentioned study was that differences in factor endowment, especially in the variation of import and domestic production, create the greatest variations between countries in terms of industry output (e.g. machinery, transport equipment and intermediate goods).

This study adopts the decomposition analysis as used by Roy et al. (2002) in their study of the contribution of the information sectors to the Indian economy. Different to Roy et al. (2002) who only investigated a single country, this paper presents multi-country comparison enabling assessment and evaluation towards ICT sectors development in selected countries in European region.

The main idea of this method is to decompose change of output of particular sector, part by part, from both intermediate and final demands and from domestic and international sources. It means that, any change in economic output between two periods of time can be decomposed from the elements built into the output calculation. Thus, the measurement allows us to trace the change in output as a result of domestic final demand, export, import substitution and technology coefficient effects. Roy et al. (2002) define the composition factor as follows:

(1) The domestic final demand effect occurs when the increased economic output is used to fulfill 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 in 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 changes in production technology as well as substitutions for various inputs.

The following explanations explain the derivation of the model. As explained earlier, the change of output can be attributed in terms of domestic and international sources as well as intermediate and final demands.

$$\boldsymbol{x_i} = \boldsymbol{u_i}(\boldsymbol{d_i} + \boldsymbol{w_i}) + \boldsymbol{e_i} \tag{5}$$

In Eq. (5), $x_i$denotes the total output of the economy and $u_i$is the domestic supply ratio defined by $(x_i - e_i)/(d_i + w_i)$. From this equation, d_i and w_i denote the domestic sources affecting change of output, where d_i is the domestic final demand, and w_i is the total intermediate demand. In addition, e_i is the total export and thus plays as an international source affecting the change of output. Thus, from Eq. (5), the change of output is affected by domestic factor (d and w) and

Table 4
Decomposition of the change on 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	$\hat{z}R_1\hat{u}_1(A_1-A_0)x_0$

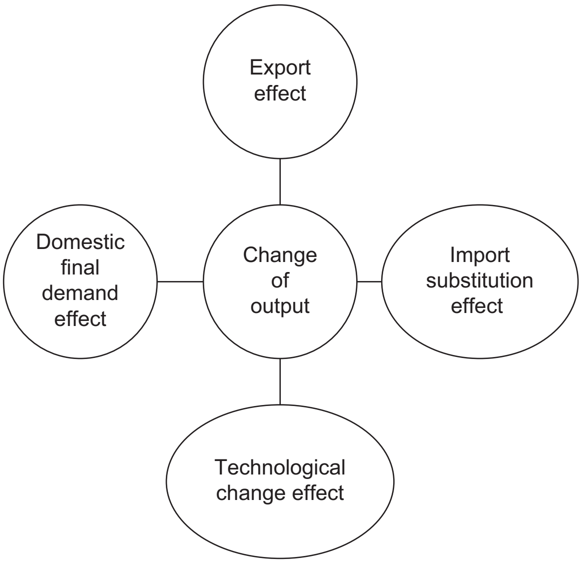

Fig. 2. Decomposition analysis.

Table 5
Selected European country and IO table availability.
Source: Eurostat (2010).

No.	Country	IO publication		
		1995	2000	2005
1	Austria	V	V	V
2	Belgium	V	V	
3	Denmark	V	V	V
4	Finland	V	V	V
5	France	V	V	V
6	Germany	V	V	V
7	Italy		V	V
8	the Netherlands	V	V	V
9	Norway*		2001	V
10	Spain	V	V	V
11	Sweden	V	V	V
12	United Kingdom	V		

international source (e).

$$\boldsymbol{x}=\hat{\boldsymbol{u}}d+\hat{\boldsymbol{u}}\mathrm{A}\mathrm{x}+\boldsymbol{e} \tag{6}$$

Eq. (6) substitutes the total intermediate demand (w) for the multiplication of the technical coefficient (A) and total output (x). Then, by introducing identity matrix I, Eq. (6) can be transformed into Eq. (7):

$$\boldsymbol{x}=(\boldsymbol{I}-\hat{\boldsymbol{u}}A)^{-1}(\hat{\boldsymbol{u}}d+\boldsymbol{e}) \tag{7}$$

Substituting $R=(\boldsymbol{I}-\hat{\boldsymbol{u}}A)^{-1}$, the above equation can be represented in Eq. (8).

$$\boldsymbol{x}=\boldsymbol{R}(\hat{\boldsymbol{u}}d+\boldsymbol{e}) \tag{8}$$

The change of output can then be decomposed based on the formula presented in Table 4:

Table 6
Classification of ICT sectors based on European 59-sector IO table.

No.	Sector number	Sector name
1	16	Printed matter and recorded media
2	23	Machinery and equipment
3	24	Office machinery and computers
4	25	Electrical machinery and apparatus
5	26	Radio, television and communication equipment and apparatus
6	27	Medical, precision and optical instruments, watches and clocks
7	36	Wholesale trade and commission trade services, excluding motor vehicles and motorcycles
8	43	Post and telecommunications services
9	49	Computer and related services
10	50	Research and development services
11	51	Other business services
12	53	Education services

To explain this analysis more clearly, Fig. 2 shows how the decomposition analysis is conducted together with its outputs.

The advantage of employing decomposition analysis is explained by Bekhet (2009) that the method overcomes many of the static features of IO models and hence is able to examine changes over time in the technical coefficient and sectoral mix.

The data in this study are taken from the IO tables published by Eurostat, comprising the following publications based on the availability of IO table (asterisks) for each country as shown in Table 5.

In terms of the countries investigated, this study attempted to replicate the coverage by Gould and Ruffin (1993), van Ark et al. (2008), and Eichengreen (2008) of 12 selected European countries that have experienced an advanced level of technological development. However, given the limited data for some countries in a particular year and due to constraints imposed by decomposition analysis, which requires at least two time periods to for an investigation, the complete analysis could only be done for 9 countries that have complete sets of data for 1995, 2000 and 2005.

The definition of ICT sectors is based on the OECD (2009). The classification is intrigued on the need for statistics and analysis to support in a common statistical standard which can be used uniformly to evaluate information society within the OECD countries. In this regards, there are two categories which are attributed to the ICT sectors: ICT product and media and content product.

> *"ICT products must primarily be intended to fulfill 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)*

In acquiring the appropriate database, the OECD definition of the ICT sectors is matched to the European input–output table. Table 6 shows the detailed classification of the sectors grouped as the ICT sectors based IO 59 table. This transformation process is conducted by looking the detail explanation of ICT sectors based on ISIC (OECD, 2009) and detailed national income accounting sector based on Eurostat, where the IO table also adopts this classification.

Table 6 exposes that there are 12 ICT sectors among the 59 sectors in the European IO table from both ICT products and media and content products. Thus, the economic impact and the contribution of the ICT sectors in this paper correspond to these 12 sectors. Appendix A elaborates the matching process from OECD definition into national income accounting.

5. Results

The following analysis investigates the output multiplier for ICT sectors and compares its value with the non-ICT sectors in the European economy. Table 7 presents the comparison between the two groups. The numbers imply that, in 1995, each euro of spending in the ICT sectors' final demand increased economic output by as much as 1.53 euro. The table also indicates that, in general, the output multiplier for the ICT sector is smaller than for the non-ICT sectors. In other words, based on the multiplier analysis, the ability of the ICT sectors to contribute to the economy is lower than that of non-ICT sectors. To shed more light on this finding, it is helpful to investigate the factors that influence the size of ICT sectors in terms of output. The decomposition analysis for evaluating the change in the output of the ICT sectors is intended to measure the source of output change for various components: whether the change in output is mainly driven by domestic demand, export, import substitution effect or technological change effect.

Table 7
Multiplier effect.

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

Table 8
Decomposition of output change in millions of 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	−4457.78	47,886.00	EUR
Belgium	17,931.65	21,313.76	−3723.46	5192.48	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	3023.50	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	−5413.02	5901.17	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 9
Decomposition of output change in millions of specified unit of currency (2000–2005).

Countries	Domestic final demand effect	Export effect	Import substitution effect	Technological change effect	Total	Currency
Austria	8033.11	5427.39	162.76	4119.74	17,743.01	EUR
Denmark	27,737.36	14,375.22	−3666.26	7872.21	46,318.53	DKK
Finland	3904.90	2054.11	−4467.80	664.89	2156.10	EUR
France	36,774.92	−8924.68	−6602.56	24,702.56	45,950.24	EUR
Germany	38,664.14	74,957.75	−68,036.99	−42,551.83	3033.07	EUR
Italy	10,827.89	4221.06	−4730.03	12,591.31	22,910.23	EUR
The Netherlands	12,820.59	7690.18	−3304.06	4310.22	21,516.93	EUR
Norway	10,520.58	−1269.10	1512.02	−18,572.43	−7808.92	EUR
Spain	74,629.01	16,470.84	1380.26	7318.77	99,798.87	EUR
Sweden	62,807.11	−18,054.23	−28,340.64	−19,311.49	−2899.25	SEK

The decomposition in Table 8 shows that the output of the ICT sectors during the period 1995–2000 was heavily influenced by domestic demand and the export effect. To exemplify this finding, the ICT sectors' output in Finland increased by 26 BEUR during 1995–2000. From this value, 10.4 BEUR is contributed from domestic final demand, 12.6 BEUR from export effect, 278.88 MEUR from import substitution effect and 3 BEUR from technological change effect. In this respect 88% of output change is driven by domestic demand and export effects only. Correlated to 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 higher domestic final demand effects.

Furthermore, there is a clear indication that most of the European countries adopted outward-looking approaches to building the ICT sectors, in the sense that they put more emphasis on the strength of exports in the ICT sectors. Belgium, Finland, Sweden and Denmark are countries that have large export effects compared with domestic final demand. Moreover, the import substitution effect in some countries is generally negative (countries also importing ICT products), except for Finland and Spain. It means that despite a great value of exports, the countries also imported the ICT product from other countries. Nevertheless, given that the size of the export effect is far greater than that of the import substitution, European countries have a comparative advantage in these sectors. Most of the European countries also enjoy a technological change effect, hence the need to increase the technological level of other sectors to increase ICT sector output.

Interestingly, the transition during the period 2000–2005 gives a very different result, as shown in Table 9. The first impression from Table 9 is that the performance of the ICT sectors in the European countries weakened in every aspect during the period 2000–2005 compared with the period 1995–2000. This change in the ICT sectors 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 reduced. Furthermore, 3 out of 10 countries investigated show a greater import substitution effect than export effect (Finland, Italy and Sweden), indicating that these countries apparently are now acting more passively and letting firms from other countries and regions penetrate their ICT markets (more inward-looking). Therefore, assuming that the imports are perfect substitutes for domestic goods, the change of output is only attempted to provide the products that used to be imported from the rest of the worlds. Moreover, the technological effect remains positive in some countries, but with a lower value, while Sweden, which recorded a substantial positive technological change effect in the previous period, is now showing a considerable negative impact.

Based on these findings, in general, the comparative advantage of ICT products exported to the rest of the world has been reduced. A reason for this evidence can be based on the theory on globalization of innovation discussed above (Archibugi & Iammarino, 2002; Ernst, 2002; Asheim & Coenen, 2006; Peters & Schmiele, 2011): the level of internalization of the ICT sector in European countries compared with those in emerging countries is very low.

One of the possible indicator to explain rapid innovation is in terms of patent applications (Jaffe, 1986; Hanel, 1994; Graham & Mowery, 2004; Cho, Lim, Kwon, & Sung, 2008; Godinho & Ferreira, 2012). Employing, the IO methodology, Hanel (1994) investigates the relationship between changes over time in the technology matrix (based on patent application) to understand the sources of information for innovation and its diffusion, and also the effects of technological change on productivity.

In the view of this indicator, IPTS, (2011) has reported that the annual number of ICT priority patent applications by inventors based in Asia has strongly increased since the early 1990s from only 3600 in 1990 to 91,000 in 2007 (excluding Japan). Most of this growth is attributed to 2 countries: South Korea and China. The annual figure in South Korea has reached almost 50,000 in 2004 and then stayed at this level, whereas in China, there has been a spectacular increase started in 2000 when annual figures exceeded 40,000 in 2007, significantly above the annual figures for both the EU and the US.

In responding this rapid development, the US firms seem to be more active than EU ones in international collaborations in ICT R&D supported by the fact that the share of US-owned foreign ICT inventions is significantly higher than the corresponding measure for the EU. In other words, US companies have sought a first mover advantage in developing ICT R&D collaborations with Asia realizing that Asia has developed into a centre of ICT growth thanks to rapid innovation (IPTS, 2011).

Conclusion

The study concludes that where the calculation of the output multiplier is concerned, the ICT sectors contributed to a lower multiplier effect than non-ICT sectors. On average, the multiplier effect for the ICT sectors ranged from 1.5 to 1.6 for 1995–2005, while the non-ICT sectors were in the range of 1.6–1.7. In addition, the decomposition analysis for the period 1995–2000 showed that the output from ICT is heavily dependent on the domestic demand and export effects. There is a clear indication that most of the European countries were outward-looking in building their ICT sectors, in the sense that they put more emphasis on the ICT sectors' export strength. In addition, most of the European countries are enjoying a technological change effect. This means that the ICT sectors are making a visible contribution to supporting the production processes of other sectors.

During the period 2000–2005, however, 3 out of 10 investigated countries had a greater import substitution effect. This means that the countries are now acting more passively and letting other countries and regions in the rest of the world penetrate their ICT markets. The domestic final demand effect is still the dominant source of output growth, but with a lower magnitude and export effect. The technological change effect remains positive but with a lower value, strengthening the finding that the link between ICT sectors and the rest of the economy is no longer strong.

Relating the results of the study to previous studies on the importance of R&D activities in the innovative sector (Peters & Schmiele, 2011), Ernst (2002) on the knowledge diffusion, Archibugi and Iammarino (2002) on triadization of knowledge and innovation, and Asheim and Coenen (2006) on increasing global competition from newly industrialized countries, the decline in the ICT sectors in the EU countries could be seen as the outcome of the evidence that ICT product is no longer competitive, especially when supported by the lower intensity of the R&D activities and weaker linkage to the other emerging countries, especially in Asia.

Appendix A

A.1. ICT sector definition

The fact that the ICT sectors have contributed to the performance of economy overall and of many other sectors has been shown by many empirical studies. The OECD has identified a need for statistics and analysis to support and store information in a common statistical standard which can be used uniformly to evaluate information society within the OECD countries (OECD, 2009). The OECD documents in details the definitions and limitations of the classification of the ICT sectors. Two categories of industries are differentiated, which are attributed to the ICT sectors: ICT products and media and content products.

Table A1
The classification of ICT products.
Source: OECD (2009).

No	ISIC-4 digits	Definition
1	2620	Computer and peripheral equipment
2	2630	Communication equipment
3	2640	Consumer electronic equipment
4	2610, 2630, 2680	Miscellaneous ICT components and goods
5	2610, 2630, 2640, 2680	Manufacturing services for ICT equipment
6	5820	Business and productivity software and licensing services
7	6202	Information technology consultancy and services
8	6110, 6120, 6130	Telecommunications services
9	7730	Leasing or rental services for ICT equipment
10	9511, 9512	Other ICT services

Table A2
The classification of content and media products.
Source: OECD (2009).

No	ISIC-4 digits	Definition
1	5811	Printed and other text-based content on physical media, and related services
2	6010, 6020	Motion picture, video, television and radio content, and related services
3	5911, 5912	Music content and related services
4	5820	Games software
5	5812	On-line content and related services
6	7310, 6391	Other content and related services

Table A3
Classification of ICT sectors based on European 59 sectors TO table.

No	Sector number	Sector name
1	22	Printed matter and recorded media
2	29	Machinery and equipment
3	30	Office machinery and computers
4	31	Electrical machinery and apparatus
5	32	Radio, television and communication equipment and apparatus
6	33	Medical, precision and optical instruments, watches and clocks
7	51	Wholesale trade and commission trade services, except of motor vehicles and motorcycles
8	64	Post and telecommunications services
9	72	Computer and related services
10	73	Research and development services
11	74	Other business services
12	80	Education services

"ICT products must primarily be intended to fulfill or enable the function of Information processing and communication by electronic means, including transmission and display"

(*OECD, 2009*)

"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)

Table A1 shows a detail classification of ICT products, whereas, Table A2 displays content and media products.

Having described the object of study on the ICT sectors, the next step is to design a compatibility chain between the definition of ICT sector and national income accounting (NIA). The author implements the conversion of ICT sectors based on OECD (2009) on Tables A1 and A2. The category is then matched up with the statistical classification of economic activities in the European Community, abbreviated as NACE, where the sectoral category based on IO table is also derived from Eurostat databases.[6] The IO table itself consists of 59 sectors as the template for further analysis.

[6] The Eurostat classification of national income accounting where the IO sector category is also based on can be found in the following link: http://ec.europa.eu/eurostat/ramon/nomenclatures/index.cfm?TargetUrl=LST_NOM_DTL&StrNom=NACE_1_1&StrLanguageCode=EN&IntPcKey=&StrLayoutCode=HIERARCHIC.

Applying the matching process for each ICT and content and media products, the following Table A3 is the results of conversion from the ICT sectors (OECD, 2009) based on ISIC to national income accounting and IO sector categories. To exemplify the matching process, a manufacturing of laser printer is included as ICT products based on OECD (2009), belonged to the sub group "computer and peripherals" with the ISIC code 2620. This product is matched with NACE category based on Eurostat as the "*manufacture of computers and other information processing equipment*" which is classified into sectoral code number 30 in the IO table.

Table A.3 shows the complete category of ICT sectors based on IO sector classification.

Table A3 shows that there are 12 ICT sectors among the 59 sectors based on the European IO table. Thus, the economic impact and the contribution of the ICT sectors in this study correspond to these 12 sectors.

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