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## Conference Paper

# On the ICT Economy in the European Countries: Investigating the Contribution of the ICT Sectors Using the Input-Output Model

21st European Regional Conference of the International Telecommunications Society (ITS):  
"Telecommunications at New Crossroads: Changing Value Configurations, User Roles, and  
Regulation", Copenhagen, Denmark, 13th-15th September 2010, No. 29

### Provided in Cooperation with:

International Telecommunications Society (ITS)

*Suggested Citation:* Rohman, Ibrahim Kholilul; Bohlin, Erik (2010) : On the ICT Economy in the European Countries: Investigating the Contribution of the ICT Sectors Using the Input-Output Model, 21st European Regional Conference of the International Telecommunications Society (ITS): "Telecommunications at New Crossroads: Changing Value Configurations, User Roles, and Regulation", Copenhagen, Denmark, 13th-15th September 2010, No. 29, International Telecommunications Society (ITS), Calgary

This Version is available at:

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**21<sup>st</sup> European Regional ITS Conference  
Copenhagen, 13-15 September 2010**

**Ibrahim Kholilul Rohman, Erik Bohlin**  
**On the ICT Economy in the European Countries:  
Investigating the Contribution of the ICT Sectors Using the  
Input-Output Model**

Investigating the Contribution of the ICT Sectors Using the Input-Output Model

Previous studies have been devoted to investigating the future of economic growth and examining the importance of technology and the ICT sectors in accelerating the growth of the economy. These studies are from a macro perspective that emphasizes the role of infrastructure investment, as well as from the firm level analysis, which is mainly related to cost efficiency. In addition, recent studies of the European countries indicate that the region is now facing a weakening effect regarding the contribution of the knowledge economy, which slows economic growth. This study aims at investigating the contribution of the ICT sectors in driving economic performance in the European economies with a sectoral approach using the Input-Output (IO) methodology. The method measures the contribution of ICT sectors based on the OECD's definition (2009) and decomposing it into several variables. In addition, the study focuses on investigating one decomposition factor related to technological change effects. The results indicate that the growth of ICT sectors' output declined considerably during 2000-2005 compared to 1995-2000. The decomposition analysis found that the ICT sectors have lost the advantage of export and technological change effects. It has also been ascertained that the smaller impact of technological change effects is due to the lack of connection between the ICT sectors and other sectors on the production side. At country level, this analysis consistently explains this phenomenon, especially in Germany and Spain but fails to detect it in France, where the technological change effect remains stable given the lack of connection between ICT sectors and the rest of the economy.

**JEL codes:** O11, O14, O32, O33, N84

**Key words:** structural change, economic growth, ICT sectors, input-output, multiplier

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## 1. Background

It has been almost two centuries since the traditional model of Malthusian economic growth theory introduced the role of technology as a predictor of the performance of economies. Malthus in the late 18<sup>th</sup> century predicted that expanding population growth combined with limited resources and declining productivity leads only to a subsistence income. With technological advances, new products appear to beget other products, and thus technology seems to be advancing at an ever increasing rate (Malthus, 1798). The Neoclassical growth model maintains that long-term economic growth will be dependent upon the saving rate (Harrod, 1936; Domar, 1947) and technical progress (Solow, 1956, 1957). Thus, the contribution of technology was especially highlighted by the Solow growth model, which gave more emphasis to technology, even though capital accumulation was still the centre of interest with technology being treated as an exogenous factor.

Paul Romer's well-known articles in 1986 and 1990 stressed the importance of technology as a driving factor increasing returns of the production function and accelerating the achievement of a higher rate of economic growth. In his study in 1986, Romer suggested that by including knowledge as an input in the production function, the growth model generated different results compared to a traditional diminishing-returns factor of production. Hence, the growth rate can increase over time. Moreover, in his study in 1990, Romer added that the additional portion of human capital constituted by research and development is undoubtedly an even stronger determinant of the rate of growth.

Parallel to the theoretical studies conducted by Romer, Barro (1991) presents the phenomenon of economic growth by focusing on the disparity between developed and developing countries. To obtain his results, an empirical study was conducted comprising 98 countries during the period 1960-1985. That study predicted that there will be a future convergence of economic growth between countries. However, poorer countries can only catch up with the richer countries if the former can reach a higher level of human capital. Thus, there is a need to include more technological development and innovation as the catalyst in fostering economic growth.

Prior to the 1990s, the empirical evidence in the Information and Communication Technology (ICT) sectors supported the theory of economic growth that envisaged a future convergence of growth between countries. Antonelli (1991) found that every dollar per capita increase in investment, especially in the telecommunications sector, creates a stronger diffusion effect in countries that were late starters, and a weaker effect in countries that started earlier. In summary, the role of the ICT sectors is like the role played by human capital in the convergence hypothesis in growth theory.

This study is conducted differently in comparison to other previous studies which is aimed at compromising between the advantages of both macro and meso levels analysis. For instance, Brynjolfsson and Hitt (2000) argued that the firm level of analysis is a more appropriate approach to investigate the productivity impact of ICT. However, relying on meso studies can also lead one into the trap of a productivity paradox where the contribution of ICT, according to Brynjolfsson (1993), is not absorbed in statistical reports (quoted from Solow, 1993). Moreover, the meso analysis also has the problem in relation to identification of the indirect effect of ICT investment (Lucas, 1999). Therefore, this study has found that there is a gap between the analyses on the macro level and meso level to explain the contribution of the ICT sectors to economic growth.

The analysis is different from many previous studies since it investigates the impact of ICT sectors on a more detailed sectoral level, utilizing the definition of the OECD (2009) and the Input-Output (IO) Table of the European countries published by Eurostat. The study also elaborates more fully the concept of “the contribution of technology and innovation” based on the study by van Ark, Mahony and Timmer (2008) as well as “the measurement of improved technology growth” based on Steindel and Stiroh (2001). More importantly, the study is conducted at country level, thus enabling an investigation of which country has higher technological effect, as well as at sectoral level within the European countries.

Based on the previous explanation, the study attempts at answering the following three research questions:

*RQ1. How much have the ICT sectors contributed to the output of the European countries' economy during the 1995-2005 period?*

The first research question is concerned with the identification of ICT sectors. This question is investigated by calculating the contribution of ICT sectors to the economy in terms of output, GDP, export and intermediate demand (which indicate the relatedness to the rest of the sectors). In addition, multiplier analysis is used to show how the change of 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 in the European economy.

*RQ2. What are the determinants that affect the output of ICT sectors in the European economy?*

The second research question is designed in connection with the need for observing the factors that affect the change of output. The basic model of equilibrium demand and supply implies that the change of output in a particular product can be composed of four sources: the domestic final demand effect, export effect, import substitution effect and technological change effect. This research question aims at finding out the most important decomposition factor, as well as discovering which decomposition factors have to be considered further.

*RQ3. How can the determinant related to the technological change effect of ICT sectors be detected?*

The third research question originates from the second one. Having obtained the measurement of technological change effect, the third question concerns further analysis to reveal how the technological effect can be detected. The technological effect is related to the position of a sector among the other sectors of the economy. Causative analysis can indicate whether the sectors become more internalized (externalized) and where the change of final demand is mainly absorbed by the other sectors. In addition, the method investigates whether the other sectors give greater feedback through the interrelatedness of production processes to the ICT sectors.

The paper is presented in the following sections: section one is introduction, section two discusses ICT economy in European countries at a glance, section three presents previous studies on the relationship between technology, ICT sectors and economic growth.. The methodology of study and data are elaborated in section four while the results are showed in section five. Section six concludes the study.

## 2. ICT Economy in the European countries

The study by van Ark, O'Mahony and Timmer (2008) throws light on the idea of further investigating the ICT sectors in the European economy. Their evidence shows that the contribution of ICT sectors, namely the knowledge economy, has dropped from the 1980s to the 2000s as shown in the following Table 1.

**Table 1** Contribution to growth of real output in the market economy, European Union 1980-2004 (%)

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	2.4	1.5
	Composition		
4	Labour composition	0.3	0.2
5	Capital services per hour	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	1.6	1.1

Source: van Ark, O'Mahony and Timmer (2008)

Table 1 reveals that although the European countries enjoyed a higher contribution of ICT capital during 1995-2004 than in the previous decade, in terms of knowledge economy the contribution to productivity has been declining. The contribution of multifactor productivity, which reflects the overall efficiency of the production process, declined from 0.9 to 0.3 percent between these two periods. As the results, the knowledge economy, which is the summed contributions of three factors: direct effects from investments in information and communication technology; changes in labor composition (mostly driven by greater demand for skilled workers); and multifactor productivity growth also reduced from 1.6 to 1.1 percent. Furthermore, a comparative study in selected European countries shows that the contribution of ICT sectors to economic growth varies between countries as shown in the Table 2.

**Table 2** Contribution to growth of real output in market economy, 1995-2004 (%)<sup>1</sup>

<b>Countries</b>	<b>Market economy</b>	<b>ICT Production</b>	<b>Goods production</b>	<b>Market services</b>
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)
Netherlands	2.0	0.4	0.6	1.1
Spain	0.2	0.1	0.1	0.1
European Union	1.5	0.5	0.8	0.5

Source: van Ark, O'Mahony and Timmer (2008)

The contribution of the ICT production varies between countries; Finland is the most prominent country in terms of having the highest contribution of ICT sectors as shown in Table 3. The growth of ICT sectors in Finland is even higher than that of other sectors, namely goods and services. The Netherlands and Germany are also considered to have a fairly high contribution of ICT sectors although the growth rate is lower than for goods, while the other countries have a lower contribution compared to the average level of ICT sectors.

In addition, van Ark, Mahony and Timmer (2008) conducted a comparative analysis between the productivity rate in the United States and the Europe. The study reveals a slowdown of productivity and contribution of ICT sectors to economic growth in the European countries as compared to the US. Additionally, the slowdown is attributable to 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, shows the disparity of growth between the two regions.

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<sup>1</sup> van Ark, O'Mahony and Timmer (2008) explain that the information and communications technology production includes manufacturing of electrical machinery and post and telecommunications services. Goods production includes agriculture, mining, manufacturing (excluding electrical machinery), construction, and utilities. Market services include distribution services; financial and business services, excluding real estate, and personal services. The market economy is the sum of three products. Numbers may not total exactly, due to rounding.

**Table 3** Average annual growth rate of GDP, GDP per capita and GDP per hour worked, EU-15 and United States, 1950-2006 (%)

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

Source: van Ark, Mahony and Timmer (2008)

Table 3 presents the disparity between the European economy and the US in terms of productivity and GDP per capita. Having reached more rapid economic growth since the 1950s, the European economy was eventually surpassed by the US beginning in the mid-1990s. Referring back to Table 1, the dramatic decline of the contribution by ICT sectors and knowledge economy is considered as being among the reasons for the productivity gap between the two regions inferred by the study.

### 3. Brief review of previous work

Many studies have been conducted investigating the growth theory in a general perspective (Romer, 1990; Barro, 1991), the relation between technology and economic performance in macro analysis (Bresnahan and Trajtenberg, 1995; Steindel and Stiroh, 2001), and the relation between technology and firm and organization at meso level (Chacko and Mitchell, 1998; Brynjolfsson and Hitt, 2000). More importantly, there have been quite a substantial number of studies discussing the role of ICT products and sectors in leading economic performance. These have focused on areas such as telecommunications (Cronin et al., 1991; Madden and Savage, 1998; Dutta, 2001), computer technology and broadband (Jorgenson and Stiroh, 1995; Brynjolfsson, 1996) and explaining the relationship between network externalities and economic performance (Riggins, Kriebel and Mukhopadhyay, 1994; Antonelli, 1994). In general, these studies indicate that the relationship between technology in generic forms and ICT products and services is important in order to achieve better performance and economic growth. However, the impact depends greatly upon the magnitude of these causalities between the driven variables at macro level (investment and infrastructure activities, the network effect on other sectors, the higher quality and human capital) and the meso level (how the ICT can support the efficiency and managerial development at firm level).

The following Table 4 gives explanation on previous studies both theoretical and empirical analyses discussing the importance of technology, in general, and ICT sectors, in particular, from the macro and meso levels. The analysis is utilized for the basic foundation in the study of the contribution of ICT sectors to the European economies.

**Table 4** Summary on the literature review: the importance of technology and ICT sectors

No.	Main ideas	Supporting studies
1.	Technology (where ICT sectors are the dominant aspect as part of general purpose of technology) plays an important role in supporting economic growth through capital accumulation and increased productivity.	Romer (1990), Barro (1991), Gould and Ruffin (1993), Bresnahan and Trajtenberg (1995), Steindel and Stiroh (2001), OECD (2009)
2.	Adding infrastructure in ICT sectors increases the growth of economy. Even though the impact is also dependent upon the market structure and the level of critical mass (infrastructure threshold), in general there is unidirectional or bi-directional causality between these two variables.	Roller and Waverman (2001), Torero, Chowdhury and Bedi (2002), Shiu and Lam (2008).
3.	Due to the network externalities embedded into the nature of ICT sectors, these sectors have the ability to increase production efficiency levels (infrastructure sharing, diffusion and innovation, etc) which relate to supply side network externalities. In addition, they also generate greater output by maintaining critical mass and absorbing positive feedback from the consumer or what are known as demand side network externalities.	Antonelli (1994), Varian (2004), Davis (2007), Maede and Islam, (2008), Waverman, (2008).
4.	The structure of ICT industries is associated with greater skills and education and further strategic alliances, as well as the creation of efficiency, cost savings and better quality from meso analysis on firms and industry level	Brynjolfsson and Hitt (1997), Chacko and Mitchell (1998), Bresnahan, Brynjolfsson and Hitt (2000),
5.	ICT devices: mobile telephony, computers and broadband have contributed to the economic growth. The mobile phone, especially, has created leapfrogging opportunities for some developing countries.	Brynjofsson and Hitt (2003), Sridhar and Sridhar, (2004), Katz et al. (2009.a) Crandall et al. (2003)

Table 4 reveals that the important contribution to economic growth by ICT sectors has been identified from many perspectives. The link can be addressed from macro analysis (mainly 1, 2 and 5) as well as meso analysis (mainly 3 and 4). In general, the role of technology (and ICT sectors) is crucial for creating higher levels of human capital, increasing productivity levels, producing efficiency on industry level and creating a network effect for the rest of sectors of the economy<sup>2</sup>.

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<sup>2</sup> 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. Therefore the analyses of industrial districts, clusters, regions, inter-firm industrial organization, national innovations systems, and networks all fall under the heading of meso economics from the evolutionary perspective



#### 4. Methodology of study

The flow of transaction on the IO table can be explained in the following system equation (1.1). Suppose we have four sectors in the economy.

$$x_{11} + x_{12} + x_{13} + x_{14} + C_1 = x_1 \quad (1.1)$$

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

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

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

From equation 3.1  $x_{ij}$  denotes the output from sector  $i$  which is used by sector  $j$  as an intermediate input (or in the other words, it reflects the input from sector  $i$  which is used for further production process in sector  $j$ ). On the IO quadrant, these values are located in quadrant 1. Moreover,  $C_i$  refers to total final demand of sector  $i$  whereas  $x_i$  refers to total output of sector  $i$ .  $C_i$  is put in quadrant 2.

Introducing the matrix notation, we can modify equation (1.1) to obtain the following matrix column:

$$x = \begin{pmatrix} x_1 \\ i \\ x_4 \end{pmatrix}; c = \begin{pmatrix} c_1 \\ i \\ c_4 \end{pmatrix} \quad (1.2)$$

Equation (3.2) consists of two matrices which show the other representation of total output and total final demand. Thus, from (1.2)  $x$  denotes the column matrix of output and  $c$  is the column matrix of the final demand. The following matrices  $I$  and  $A$  are the identity matrix and technology matrix respectively

$$I = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}; A = \begin{bmatrix} a_{11} & \dots & a_{14} \\ \vdots & \ddots & \vdots \\ a_{41} & \dots & a_{44} \end{bmatrix} \quad (1.3)$$

The left-hand side of (1.3) is the identity matrix; a diagonal matrix whose off-diagonals are zero. Furthermore,  $A$  is the technology matrix which consists of the ratio of the intermediate demand to the total output,  $\frac{x_{ij}}{x_i}$ . Hence,  $a_{14}$ , for instance, explains the ratio of output from sector 1, which is further used to produce their output by sector 4, divided by total output from sector 1.

Combining (1.1), (1.2) and (1.3), the equilibrium of the equation for demand and supply in (1.1) can be modified as follows:

$$Ax + c = x \quad (1.4)$$

$$(I - A)x = c$$

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

The first row of (1.4) is the general form of equation (1.1). Then, from (1.4), the multiplier is defined as the inverse Leontief matrix,  $(I - A)^{-1}$ . The multiplier measures the ratio of output changes in the equilibrium as the result of the change in the final demand. Therefore, the output multiplier measures total change throughout the economy from a unit change in final demand. The change in the final demand might arise from private consumption, government expenditure, investment and export. As the consequence of production linkages, a change of output will be larger than a change in the final demand. For instance, if the final demand of the ICT sector (e.g. additional purchasing of personal computers) increases by 10 unit values of money, the output in the economy will grow by more than 10 unit values of money or as much as the multiplier coefficient of this sectors. (Additional purchasing of personal computers leads to increased packaging services and transportation services, for instance)

Throughout this study, the investigation on the IO table is conducted in constant analysis to be appropriate for growth measurement. Therefore, since the IO is calculated based on current prices, a GDP deflation is used to change all the value into constant terms. The GDP deflator data is gathered from the World Bank.

#### 4.1. Multiplier analysis

The most convenient way to explain the variety of multiplier analysis derived from the IO model can be started by recalling equation (1.5) as follows:

$$Ax + c = x \tag{1.5}$$

$$(I - A)x = c$$

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

From equation (1.5) the basic distinction between multiplier is especially related to the type of IO table and the structure of Leontief matrix:

- A simple multiplier measures the impact both from direct and indirect impact thus the matrix  $(I - A)^{-1}$  consist of all sectors within the economy putting household exogenous (Miller and Blair, 1999, p.245). Hence, the dimension of the matrix is 59 x 59 in the case of European Input Output table. The IO table used in this method is open IO.
- Total multiplier measures the total impact from direct, indirect and induced impact, hence, the inverse Leontief matrix  $(I - A)^{-1}$  consist of all sectors within the economy included the consumption in column 60 and wages in rows 60. The dimensions of the matrix now become 60 x 60 in the case of European Input Output table. In the other words, the IO table refers to closed IO.
- Apart from that, the multiplier can be examined whether it captures all activities within a country regardless the origin of goods or, on the contrary, only measures the domestic inter-relatedness between sectors. The first definition refers to a total transaction where the value of matrix in each quadrant is attached with the value of imported goods. The latter definition refers to domestic transaction where the value only reflects domestic activities.

The analysis of the multiplier can also be investigated through the distinction between direct and indirect impact:

- Direct impacts – the initial injection of new economic activity, e.g. a new manufacturing plant located in a state. These are the initial, immediate effects caused by a specific activity (i.e. employment and income). Direct impacts initiate subsequent rounds of income creation, spending and re-spending, and result in indirect effects/impacts.
- Indirect impacts – the sum of inter-industry purchases through all the rounds of purchasing. The effects that result from the forward and backward linkages that produce the direct effects – (e.g. the agricultural sector indirectly support jobs in the manufacturing sector). It is the changes in production, employment, and incomes etc. which occur as a result of the direct effects.

This study corresponds to the method of simple multiplier, direct impact and domestic transaction model. Hence, in calculating the multiplier only goods and services produced domestically affect the value of the multiplier. Furthermore, the multiplier utilizes the open IO instead of the closed one. In the choosing this option, a previous study by Grady and Muller (1988) suggested the use of closed IO table usually creates a misleading result since it yields exaggerated estimates of the impact of program expenditures on the economy. This is the case because closed IO models do not take into account the macroeconomic feedbacks that tend to cause the multiplier to decrease over time. At the end, the use of open IO tables which puts all final demand categories, including consumption, as exogenous variables, is recommended

#### 4.2. Decomposition analysis

The study of factor decomposition analysis cannot be separated from the study proposed by Chenery (1960) to identify source of structural change and industrial growth. One of conclusions the study mentioned 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) where economic of scale are most important. Long before this study, Blomqvist (1990) urged attention to Fisher (1939) and Clark (1940), among others, who were the first to introduce the concepts of primary, secondary and tertiary sectors, which are currently still widely used. 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. The basic methodology has been extended in several ways. Chenery et al. (1963), for example, incorporated some elements of trade into the framework while Carter (1960) paid more attention to the role of investment in influencing technical changes.

This study utilizes the decomposition analysis adopted by Roy, Das and Chakraborty (2002) investigating the contribution of the information sectors in the Indian economy. The derivation of the model in both studies is explained below

$$x_t = u_t(d_t + w_t) + e_t \tag{1.6}$$

From equation (1.6), it can be explained that  $X_i$  denotes the total output in the economy,  $u_i$  is the domestic supply ratio defined by  $(x_i - e_i)/(d_i + w_i)$ . Moreover this matrix has the off

diagonal equal to zero.  $d_i$  denotes domestic final demand while  $w_i$  and  $e_i$  are the total intermediate demand and total export respectively.

$$x = \hat{u}d + \hat{u}Ax + e \tag{1.7}$$

Equation (1.7) is the same as (1.6) which substitutes the total intermediate demand as the multiplication of the technical coefficient and total output.

$$x = (I - [\hat{u}A])^{-1}(\hat{u}d + e) \tag{1.8}$$

Equation (1.8) is done by introducing the identity matrix, and putting  $x$  in the left hand side of the equation.

$$x = R(\hat{u}d + e) \tag{1.9}$$

Substituting  $R$  as  $(I - [\hat{u}A])^{-1}$  the above equation can be represented in the following equation (1.10)

$$R = (I - [\hat{u}A])^{-1} \tag{1.10}$$

Now, following Roy et al. (2002), the decomposition of the change of economic output between two periods of time can be summarized in the following Table 5.

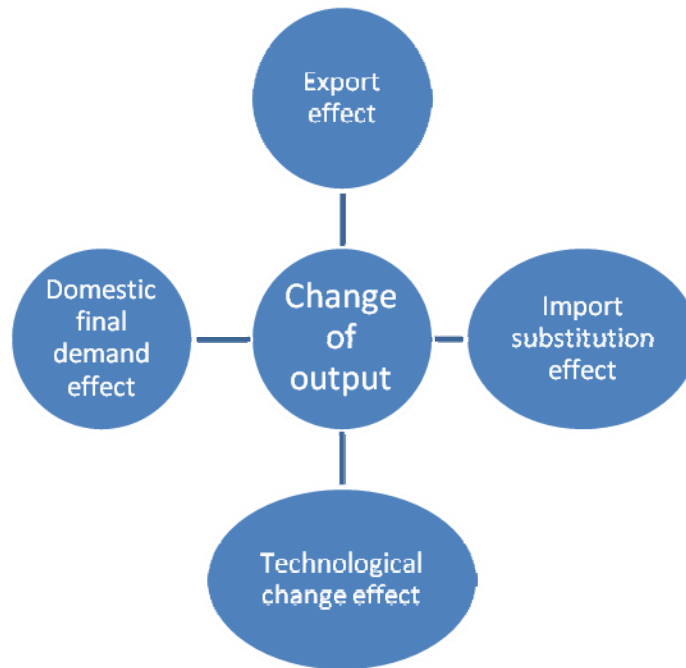
**Table 5** Decomposition of the change on economic output.

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

From Table 5 it can be verified that any change on the economic output between two periods of time can be decomposed, part by part, from the elements built into the output calculation. Thus, the table 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), defines the composition factor as follows:

1. The domestic final demand occurs when the increased of economic output is devoted to fulfil 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 is occurred 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.

To explain this analysis more clearly, Figure 1 shows how the decomposition analysis is conducted and what the outputs of the analysis are



**Figure 1** Decomposition analysis

Bekhet (2009) explains that decomposition analysis is a popular methodology for a number of reasons. The first reason is that the method overcomes many of static features of IO models and is able to examine changes over time in technical coefficient and sectoral mix. In addition, the advantage of the analysis is in relation to pragmatic alternatives to econometric estimation since such the same purposes using econometrics model require at least 15 years or more of observation. The method also captures the response of output as a result of prices changes (which, however, is not discussed in this study).

As to the technological change effect which becomes of interest in the decomposition analysis, Skolka (1989) explains that this effect creates a shift in the input coefficient on IO table which occurs due to the following reasons: (i) substitution of intermediate inputs: certain raw materials are substituted by others, (ii) changes in division of labour, parts and semi-finished products produced by certain establishments are externalized and purchased from other establishments, (iii) change in the composition of output: innovation, shift in relative price and changing demand affect the output mix by industries.

#### **4.3. Structural change and the causative matrix**

De Mesnard (2008) summarizes that the analysis of structural change can be found in many areas. In sociology, it can be used to investigate how communication between individuals varies, in finance theory it concerns with the evolution of shareholding. In economics, especially using the input-output method, this approach is used to determine the change of the structure of production (i.e. structure of exchange between sectors of

production) over time in spatial and regional analysis. The method enables us to respond to the difference between countries or to differences in space and time.

The derivation of the causative matrix employing the IO in this study is based on Roy, Das, and Chakraborty (2002).

$$P_{t+1} = P_t C \tag{1.11}$$

Equation (1.11) explains the relation between two matrices  $P_{t+1}$  and  $P_t$ , where the first refers to the later period. The relation of the two matrices depends upon the C causative matrix. This relation can be explained in terms of each matrix component in the following equation (1.12)

$$P_{ij}^{t+1} = \sum_k P_{ik}^t c_{kj} \tag{1.12}$$

As stated earlier that in the context of Input-Output table, the two sequences of stochastic matrices P is represented by the Inverse Leontief from the IO table. Therefore, equation (1.12) can be represented in the following equation (1.15)

$$l_{ij}^{t+1} = c_{i1} l_{1j} + c_{i2} l_{2j} + c_{i3} l_{3j} + \dots + c_{in} l_{nj} \tag{1.13}$$

Equation (1.13) is the representation of (1.11) when the p transition probability matrix is replaced by inverse Leontief  $(1-A)^{-1}$ . De Mesnard (2008) explains that in this context, C is defined as a left causative matrix explaining the change between  $l_1$  and  $l_2$ , for instance during the period t=1 and t=2. As matrix C is completely filled with n x n dimension, the matrix is then being compared to the identity matrix (I). Hence, to infer the results, all diagonal elements are compared to 1 while all of diagonal elements are compared to 0.

Roy, Das, and Chakraborty (2002) classify the result on causative matrix in the following inference in table 6:

**Table 6** Inference of Causative matrix

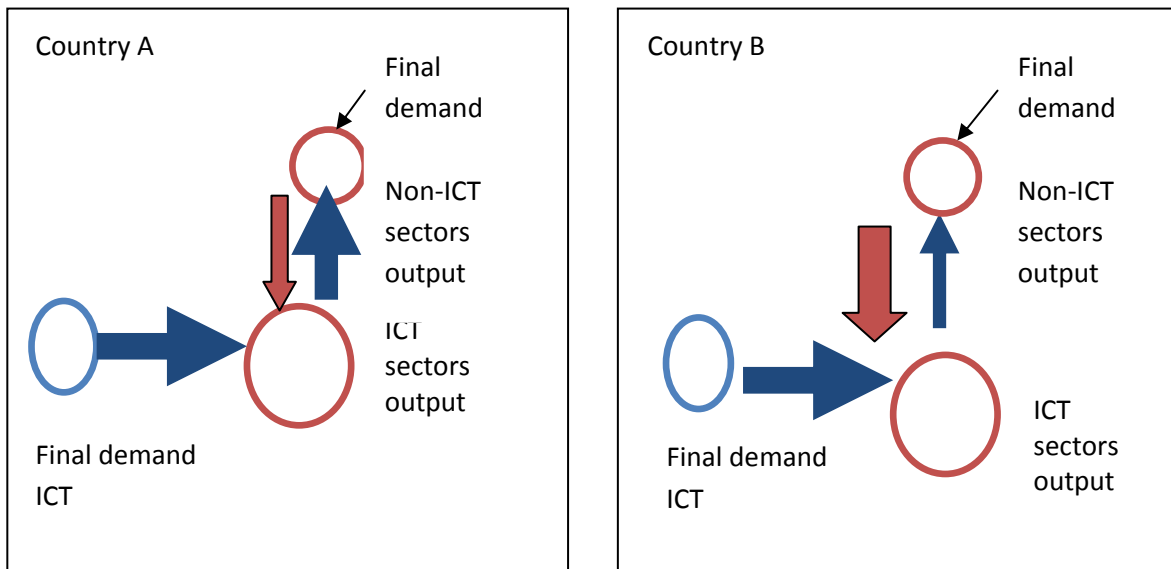
Definition	$\sum_{k=1} c_{ik} < 0.0$ Decreased output impacts generated by other sectors final demand	$\sum_{k=1} c_{ik} > 0.0$ Increased output impacts generated by other sectors final demand
<b><math>c_{ii} &gt; 1.0</math></b> Increased relative endogenization of the impact from sector i compared to the rest of sectors		
<b><math>c_{ii} &lt; 1.0</math></b> Decreased relative		

endogenization of the impact from sector i compared to the rest of sectors		
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Based on Table 6, the way to analyze this measurement is explained in the following box

- A large value of diagonal element in a causative matrix  $C_{ii}$ , where i denotes the ICT sectors, indicates that the final demand impact of sector i relative to others are increasingly being internalized within the sector
  - While, large value of off diagonal element in a causative matrix of  $C_{ij}$  where i denotes the ICT sectors and j denotes non-ICT sectors, indicates that increasing proportionate important of final demand deliveries from sector j in stimulating output of sector i.
- (Roy et al. pp.111-112)

This definition can be simplified in the case where the diagonal matrix of a causative matrix ( $C_{ii}$ ) is larger than one, and then the ICT sectors absorb all changes in the final demand to form their own output. Hence, the opposite definition is that, when the  $C_{ii} < 1$ , the change of final demand in ICT sectors is distributed to the other sectors. Thus, instead of accumulating the output for the sectors themselves, ICT sectors plays more role as becoming a catalyst. Figure 2 describes this conception of this definition by giving some examples.



**Figure 2** The mechanics of the causative matrix

Figure 2 gives the way to explain the causative matrix based on the following case. Suppose there are two countries, A and B. Both countries have an economic structure consisting of ICT and non-ICT sectors. To simplify, there are only two sectors in the

economy, computer manufacturing, which is an ICT sectors and plastic product manufacturing, which is a non-ICT sector. Furthermore, in this explanation product, sector and manufacturing are used interchangeably.

In both country A and B, an additional purchase of a computer is translated into not only the enlargement of computer industries, but also, at the same time, increases the demand for output of from plastic manufacturing as well as in country B. If the demand for computers is also creating demand for plastic manufacturing in a very significant amount, then the spreading out effect of computer manufacturing to plastic product is said to be very large. Hence, if the width of blue arrow upward indicates the impact measurement of ICT sector to non-ICT sectors, then the ICT sectors in country A is indicated as having larger spreading out effect than the ICT sectors country B. In this case, the diagonal element of causative matrix  $C_{ii}$  in country A is lower than country B which suggests the more externalized of ICT sectors and the more ICT sectors have a connection to the rest of economy in country A than in country B.

Additionally, after getting the impact from the purchasing of plastic by computer manufacturing, the plastic product manufacturing now entitled greater output. Now, instead of having two sectors in economy, there are four sectors: computer manufacturing and software manufacturing are both the ICT sectors, food products, and plastic products are non-ICT sectors. Suppose, there is an additional demand for plastic from food products; this demand creates the enlargement of the output of plastic manufacturing. Consequently, this additional demand requires the plastic industry to buy additional input for production. This is done, for instance, by buying the product from software industry (aiming at better design, branding, etc). The feedback from the plastic industry which affects the ICT sectors is indicated by the downward red arrow. In this case, country B is said to have the greater feedback from plastic industry to software industry, and hence a larger impact on ICT sectors compared to country A. Therefore, country B is indicated as having a larger  $C_{ik}$  or off-diagonal element.

The data in this study adopts the IO table published by the Eurostat comprising the following publication.

**Table 7** Selected European country and IO table availability

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		

Source: collected from Eurostat



Since the transition matrix requires at least to two time periods to investigate the structural change in the economy, the United Kingdom is then dropped from the country study. The unavailability of the UK data has been confirmed which stressed that other priority stopped the construction of Input-Output tables in the UK, but work is now in process to produce tables for 2005. This study also continues the coverage by Gould and Ruffin (1993), Ark et al (2008) and Eichengreen (2008) on 12 selected European countries that are believed to have been experiencing an advanced level of technological development.

In addition the definition of ICT sectors is designed based on OECD (2009) thus elaborating these definitions and the template of 59-sectors IO of the European countries, the coverage of the ICT sectors is in the following category.

**Table 8** Classification of ICT sectors based on European 59 sectors TO 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, except of 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

## 5. Results

The first analysis in this study compares the multiplier of ICT and non ICT sectors in the European countries investigated. The following analysis investigates the output multiplier for ICT sectors and compares the value with the non-ICT sectors in the European economy. Table 9 presents the comparison between two groups.

**Table 9** Multiplier effect

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

Source: Author's calculation

From Table 9 each 1 euro spending in the ICT sectors final demand enables the enlargement to economic output as much as 1.53 euro in 1995. The table also indicates that in general the output multiplier of ICT sector is smaller than the non-ICT sectors. In other words, based on the multiplier analysis, it demonstrates that the ability of ICT sectors to contribute to the economy from final demand effect is considered lower than that of non-ICT sectors.

The multiplier has shown that apart from the lower proportion of ICT sectors to the rest of economy, there is also a tendency for ICT sectors to have lower multiplier effects compared to non-ICT sectors in the economy in general. Therefore, there is a need to investigate the factors that influence the size of ICT sectors in terms of output. The decomposition analysis for evaluating the change in output of ICT sectors is intended to measure the source of output change to various components: whether the change of output is mainly driven by domestic demand, export effect, import substitution effect or technological change effect.

**Table 10** Decomposition of output change in millions of specified unit of currency  
(1995-2000)

Countries	Domestic final demand	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
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

Source: Author's calculation

The decomposition in Table 10 shows that the output of ICT sectors in 1995-2000 is heavily influenced by domestic demand and the export effect. Correlated to the size of economy, domestic demand and the export effect are associated with population size and the 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 in building the ICT sectors in the sense that they put more emphasis on the strength of export in ICT sectors. Belgium, Finland, Sweden and Denmark are the countries that have large export effects compared to domestic final demand<sup>3</sup>. Consequently, the import substitution effect is generally negative (countries also importing ICT products), except for Finland and Spain. Nevertheless, given that the impact of the export effect is greater than that of the import substitution effect, European countries have a comparative advantage in these sectors. In addition, most of the European countries enjoy a technological change effect; hence the need to increase the technological level of other sectors to increase ICT sector output. Moreover, the transition during 2000-2005 gives a different, as shown in Table 11.

<sup>3</sup> The discussion about outward looking and inward looking approach in trade policy can be seen in Keesing (1967).

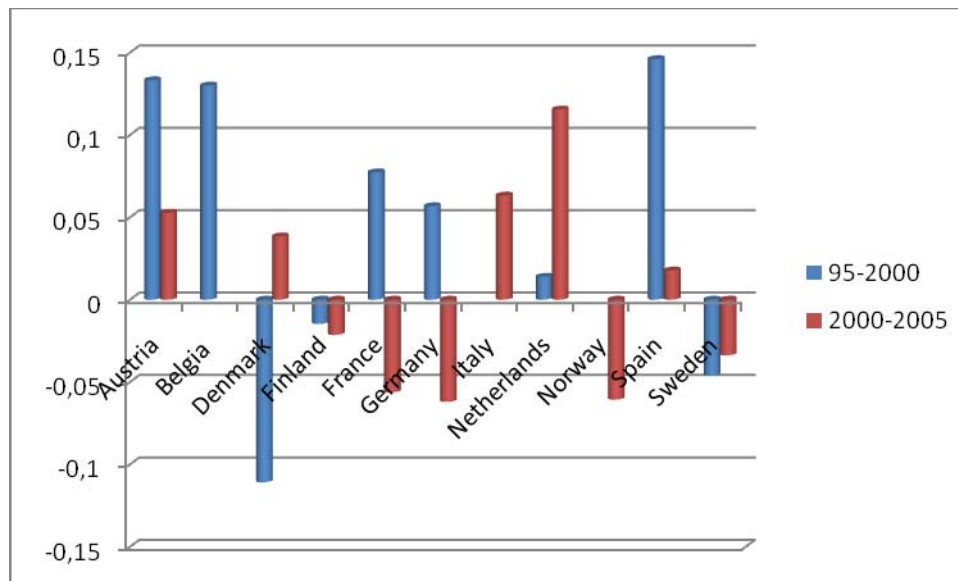
**Table 11** Decomposition of output change in millions of specified unit of currency  
(2000-2005)

Countries	Domestic final demand	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
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

Source: Author's calculation

The first impression from Table 11 is that the performance of the ICT sectors in the European countries have weakened in every aspect in 2000-2005 compared to 1995-2000. This change in ICT sectors is mainly driven by domestic final demand effect which has declined from the previous period. The export effect also decreased, with the ICT sectors of 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, 7 out of 10 countries investigated show a positive import substitution effect, meaning that these countries are now playing more passively and letting other countries and regions in the rest of the world penetrate the ICT market (more inward looking). The technological effect remains positive in some countries, but with lower value, while Sweden, which recorded substantial positive technological effect in the previous period is now showing a considerable negative impact.

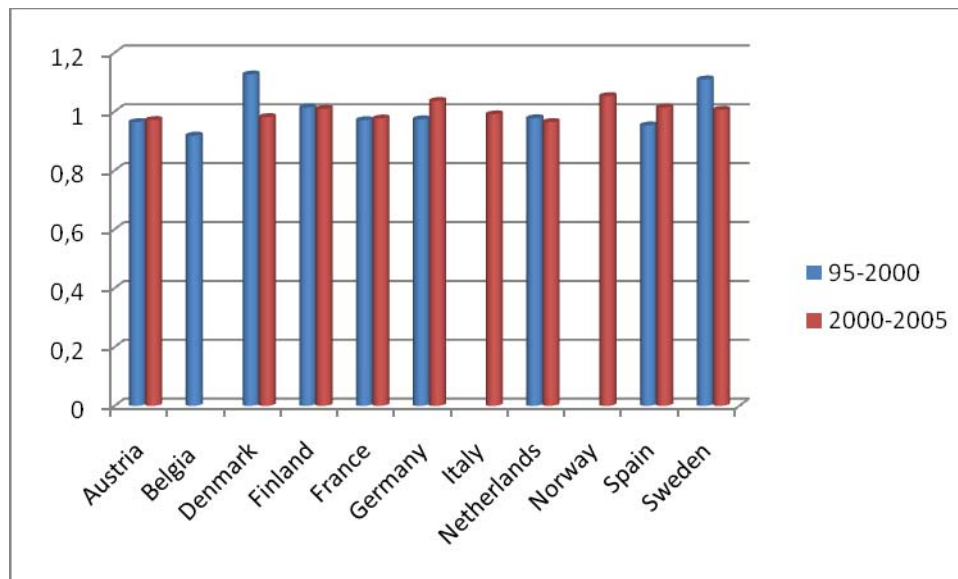
Next, the transition probability matrix is measured by multiplying the inverse Leontief following the formula on (1.13). The result is shown in Figure 3.



Source: Author's calculation

**Figure 3** ODE of ICT sectors

Figure 3 shows that most countries were enjoying the positive ODE during 1995-2000 indicating positive feedback from other sectors. This means that any additional demand for non-ICT sectors is associated with the enlargement of the ICT sectors in these countries, except for Denmark and Sweden. However, the results are different in the second period where half of countries showed negative ODE. This means that additional final demand in non-ICT sectors doesn't affect the output of ICT sectors, whereas a positive effect can be found in the Netherlands, Italy, Denmark and Austria. The Netherlands and Denmark record the highest transition regarding the creation of a greater link between the demand by non-ICT sectors to ICT sectors, especially in Denmark which shows a change from a cross border negative ODE to a positive ODE. Figure 4 shows the analysis on the diagonal element  $C_{ii}$ .

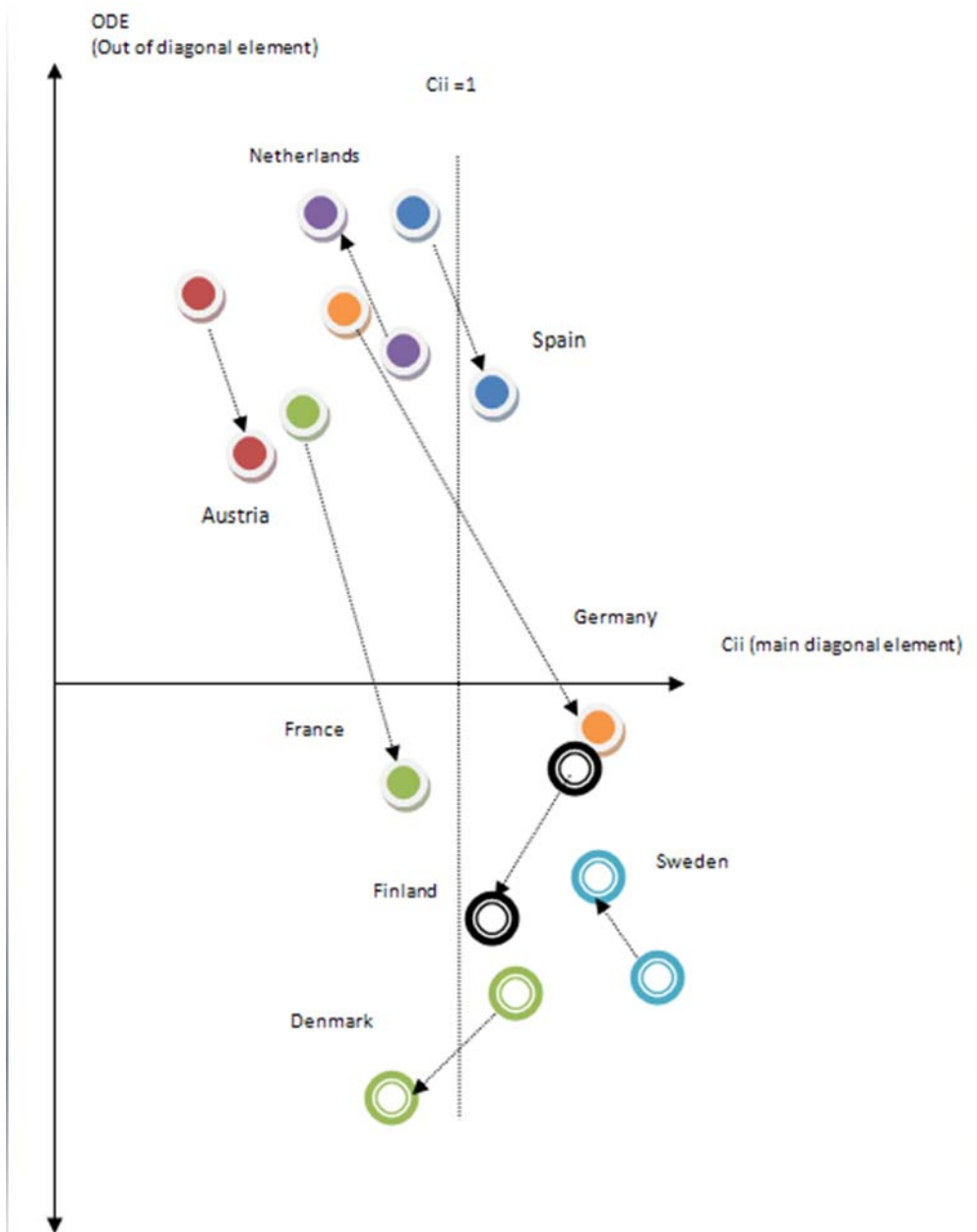


Source: Author's calculation

**Figure 4** C<sub>ii</sub> of ICT sectors

Previous exposition has indicated that any C<sub>ii</sub> less than 1 indicates that the ICT sectors are giving more spreading out effect to the rest of economy. Figure 4 shows that there are some differences in the characteristics of ICT sectors in 1995-2000 compared to 2000-2005. In the first period, 1999-2000, the figures show that the Scandinavian countries, Denmark, Sweden and Finland, have high C<sub>ii</sub> indicating that the ICT sectors are very strong internally and the connection to the non-ICT sectors is smaller. However, during the second transition period in 2000-2005, except for Norway and Germany, the impact of ICT sectors was becoming more externalized in the sense that the C<sub>ii</sub> index dropped below 1. Thus the inter-relatedness of ICT sectors to non-ICT sectors is greater.

To compile, Figure 5 summarizes the previous findings in a Cartesian diagram.



**Figure 5** The transition of ICT sectors in the European countries

Figure 5 shows irregularity of the structural change and the transition of ICT sectors in 1995-2000 and 2000-2005. The patterns are different, though, and can be summarized as follows<sup>4</sup>:

- Northwest quadrant: The ICT sectors are becoming more externalized while at the same time getting larger feedback from the non-ICT sectors
- Southwest quadrant: The ICT sectors are becoming more externalized while at the same time getting smaller feedback from the non-ICT sectors
- Northeast quadrant: ICT sectors are becoming more endogenized while at the same time getting larger feedback from the non-ICT sectors

<sup>4</sup> The quadrant is divided into four categories where  $C_{ii}=1$  and  $ODE=0$  are the threshold value for each indicator.

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

Thus, based on the direction of transition patterns, the countries can be categorized in Table 12.

**Table 12** Category of country based on the path of direction of ICT sectors

<b>More externalized and larger feedback (1)</b>	<b>More externalized and smaller feedback (2)</b>	<b>More endogenized and larger feedback (3)</b>	<b>More endogenized and smaller feedback (4)</b>
Sweden Netherlands	Finland Denmark Average European countries (Fig.4.13)		France Germany Spain Austria

The aggregate level calculation puts, on average, the European countries belongs to second category, which means that the ICT sectors are becoming more externalized but with smaller feedback as shown in Table 12. However, there are some variations between countries. The countries which have larger economies (France, Germany, and Spain) are classified into group four which means that the ICT sectors are endogenized. Thus, the ICT sectors are more unrelated to other non-ICT sectors while at the same time get smaller impact from other non-ICT sectors.

## 6. Conclusion

In summary, the study concludes that:

- From the descriptive analysis, the ICT sectors experienced a higher growth rate than the rest of the economic sectors in the European economy during 1995-2000 but decreased in the subsequent period 2000-2005. The contribution of the output by the ICT sectors to the total output has generally increased during 1995-2000 and decreased during 2000-2005. With regard to the calculation of the output multiplier, this study found that the ICT sectors contributed to a lower multiplier effect. On average, it ranges from 1.5 to 1.6 for 1995-2005, while the non-ICT sectors are in the multiplier range of 1.6 to 1.7.
- The decomposition analysis during 1995-2000 shows that the output of ICT is heavily dependent on the domestic demand and export effect. There is a clear indication that most of the European countries were outward looking in building the ICT sectors in the sense that they put more emphasis on the strength of export on ICT sectors while (still), at the same time, allowing some ICT products to be imported. In addition, most of the European countries are enjoying a technological change effect. This means that the contribution by the ICT sectors in supporting the production processes of other sectors is visible. During 2000-2005, however, seven out of ten investigated countries had a positive 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 the ICT market. The domestic final demand effect is still the dominant source of output growth, but with a lower magnitude and export effect. The technological 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.

- (iii) From the causative matrix analysis, the aggregation data of European countries found that the connection of ICT sectors to other sectors is decreasing and hence the contribution to output is affected. In other words, the ICT sectors in the European countries are unable to capture the positive feedback from the other sectors, strengthening the reason the technological effect is decreasing in most countries and most of the ICT sectors based on the decomposition analysis. In the country analysis, the study is consistent in explaining the disappearance of the technological change effect in the European countries. The ICT sectors in the countries are becoming more endogenized and are receiving less feedback from the rest of the economy (notably Germany and Spain). The study is less consistent in the case of France, however, since the ICT sectors are becoming more endogenized and has less feedback but is entitled to a greater technological change effect.

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