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ICT Diffusion, Innovation Systems, Globalisation and Regional Economic Dynamics: Theory and Empirical Evidence

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Abstract: The objective of this paper is to review the relevant theoretical and empirical literature to provide a conceptual and methodological background for the analysis of the consequences of ICT use and globalisation on the regional economies in the European Union. We highlight the key aspects of ICT as a general purpose technology, discuss the economic impacts of ICT diffusion from a macro as well as from a micro perspective, and examine the spatial consequences of ICT diffusion. We focus on regional innovation systems and globalisation in order to propose an organizing framework for the analysis of the impact of ICT diffusion on regional development.

Key words: Technology diffusion, Innovation systems, Globalisation, Regional development

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1. Introduction

Information and Communication Technologies (ICT) is no doubt one of the *key innovations* of the last century. ICT represent a new technological paradigm that belongs to the family of General Purpose Technologies (GPTs). A GPT has the potential for pervasive adoption and adaptation in a wide range or even all sectors of the economy in ways that drastically change operations and products as well as the relationships between different sectors. The characteristics of GPTs have been described by Bresnahan & Trajtenberg (1995, p.84): "Most GPTs play the role of 'enabling technologies', opening up new opportunities rather than offering complete, final solutions." GPTs also involve 'innovational complementarities', i.e. "the productivity of R&D in a downstream sector increases as a consequence of innovation in the GPT technology". Thus, GPTs have two major characteristics: *generality of application*; and, *innovational complementarities*. However, other characteristics of GPTs are also important (Lipsey, Becar & Carlaw, 1998): (i) much scope for improvement initially, (ii) many varied uses, (iii) applicability across large parts of the economy, and (iv) strong complementarities with other technologies.

Some innovations are incremental and some are drastic. ICT are an example of a drastic innovation, which qualifies as a general purpose technology (GPT), since it has shown to have the potential for (i) pervasive use in a wide range of sectors in ways that drastically change their modes of operation as well as the character of their output, (ii) setting the stage for series of incremental innovations, and (iii) producing discontinuities in the observed pattern of resource allocation and the evolution of output. ICT being a GPT has many implications: i) adoption of such a technology entails experimentation, which may lead to innovation by adopting firms, which in turns show up as total factor productivity growth, ii) as well as innovating themselves, firms can learn from the (successful or unsuccessful) innovation efforts of others, so there are spillover effects (Bresnahan & Trajtenberg, 1995), and iii) successful implementation of an ICT project requires reorganisation of the firm around the new technology (Helpman & Trajtenberg, 1998, Yang & Brynjolffson, 2001; Brynjolfsson, Hitt & Yang, 2002).

ICT are composed of a wide range of product and service technologies including computer hardware, software and services and a host of telecommunications functions that include wire or wireline, and wireless, satellite products and services. The rapid diffusion of ICT has produced important changes in how and where goods and services are produced, the nature of goods and services produced, and the means by which goods and services are brought to the market and distributed to consumers. This implies that ICT has had an impact on the industrial structure of regions and on the geographical location of different industries not only within the EU but worldwide. ICT has also influenced the relationship between customers and suppliers and the way many markets for intermediate as well as final goods and services are organised.

However, there are substantial differences among countries and regions, also among the developed economies, as regards their role in the development of ICT and their ability and propensity to adopt ICT applications in various activities and sectors (Johansson, Karlsson & Stough, 2006). This implies, among other things, that there is a substantial variation in the impact of the use of ICT on efficiency, productivity, and economic growth in different countries and regions.

The objective of this paper is to review the relevant theoretical and empirical literature to provide a theoretical and methodological background for the analysis of the consequences of ICT use and globalisation on the regional economies in the European Union (EU).

This review focuses on the following core issues and analytical questions:

ICT: Definitions and Measures

1. What do we understand with ICT as a set of technologies and as a sector of the economy?
2. How relevant is the existing statistical data for analysing different aspects of the impact and effects of ICT?

The Economic Impact of ICT Diffusion and Regional Dynamics

3. What do we know about the effects of ICT diffusion on structural change, productivity and output growth?
4. What are the effects of region-specific mechanisms, such as technological and knowledge spillovers, interactions and networking between firms, on ICT diffusion and its impact on the economic efficiency across EU regions?
5. How does ICT influence spatial patterns of economic activity and what type of regional transformations can be linked to ICT?

REGIONAL INNOVATION SYSTEMS AND ICT DIFFUSION

6. What key features characterise regional innovation systems in relation to ICT production and use?
7. What are the linkages between regional innovation systems and larger institutional frameworks at national and international levels?
8. How do regional innovation systems influence the effective use of ICT at regional level?
9. How does ICT influence the functioning of regional innovation systems?

CONSEQUENCES OF GLOBALISATION AND ICT DIFFUSION

10. What are the consequences of the interactions between ICT use and globalisation on location of economic activities?
11. What are the consequences of outsourcing /offshoring driven by globalisation and ICT use on the home and host economies?
12. What is the impact of ICT use and globalisation on regional economic performance?

The paper is organised as follows. Section 2 provides an overview of definitions and measures with the objective to provide a general conceptual framework for understanding ICT. Section 3 discusses the impact of ICT diffusion on economic performance, in particular the impact of ICT on structural change, productivity and output growth. Section 4 examines the spatial impact of ICT diffusion including ICT-related spatial transformations, the location of economic activities and the impact of ICT on regional economic growth. Section 5 provides an analysis of the key features of regional innovation systems in relation to ICT production and usage. Section 6 discusses the interactions between ICT and globalisation and their consequences on firms' organisational structures, location of economic activities, and economic performance. Section 7 summarises the main theoretical arguments and concepts and articulates an integrated framework for the analysis of the interplay between, ICT diffusion, regional innovation systems, globalisation on regional economies.

2 ICT: Definitions and Measures

At face value, ICT are a collection of technologies and applications, which enable electronic processing, storing, retrieval, and transfer of data to a wide variety of users or clients. According to Cohen, Salomon & Nijkamp (2002), ICT are currently characterised by:

- very dynamic technological changes, with rapid penetration and adoption rates;
- decreasing costs for new equipment and features;
- a rapidly increasing range of applications and penetration in an increasing number of realms of professional and personal life;
- an intertwined institutional market place, with the private sector acting in a decreasingly regulated environment (in most countries);
- a production and services package dependent on a range of qualities of skilled human resources, and
- a convergence of technologies.

Unfortunately, there exists no clear or unambiguous agreement on the definition of ICT, or what sectors should be termed ICT sectors, which has been generally accepted (Schwartz, 1990; Malecki, 1991; Graham & Marvin, 1996). Furthermore, as ICT over time penetrate more and more sectors, more and more sectors deserve to be classified as ICT sectors. However, it is possible to provisionally delineate the providers of ICT in terms i) manufacturing of ICT, ii) wholesale and retail trade of ICT, iii) ICT network services, iv) other ICT services. These providers provide ICT to ICT users, i.e. to households, firms, and public sector organisations.

To analyse the growth effects of ICT it is necessary to measure the extent of *investment in ICT* in the manufacturing sector, in the private service sector and in the public sector. Usually, statistical bureaus estimate investments from surveys among businesses specifically designed to capture investments. Based upon data over investments in well-defined asset groups, such as plant & machinery, infrastructure, dwellings, vehicles, and intangibles, such as R&D, with internationally agreed definitions, is it possible to estimate total investments by aggregation. However, this doesn't work in the case of investments in ICT due to a lack of generally agreed definitions.[1]

To develop such generally agreed definitions for investments in ICT is by no means simple for several reasons. First, the investments are of at least four kinds: *hardware, software, network infrastructure* (communications equipment), and, in principle also *training of personnel*[2] to handle the equipment but only the three first types are normally capitalised. However, even at this relatively aggregated level comparability problems remain (Ahmed, Schreyer & Wölfl, 2004). When software is sold together with hardware, its value may be recorded as either software or included in the hardware value depending upon the circumstances. ICT components included in other products, such as machinery, will not be directly recorded as an investment in ICT.[3] The implication is that comparisons of investments in ICT in the manufacturing and the service sector may be biased, since substantial expenditures on ICT in the manufacturing sector might be recorded as intermediate consumption, while they are capitalised as investments in ICT in the service sector. Furthermore, there are large differences between countries regarding the extent to which expenditures for software are capitalised. Implementing ICT in an organisation entails reorganisation costs. These adjustment costs create a stock that yields future benefits. However, this investment is not measured as such in the national accounts (Oulton & Srinivasan, 2005).[4]

Second, we have the rapid improvements in capacities and speed and at the same time a drastic drop in costs of in particular the hardware. In many cases, it isn't enough to measure expenditures on ICT at current prices. Instead a volume measure is needed that controls for changes in the price level of ICT products. Thus, price indices are needed to deflate expenditures at current price to get a 'constant price' measure. Due to rapidly decreasing production costs and strong competition, the prices of key ICT products has fallen drastically in recent decades. At the same time, their capacity has

[1] The problems of measuring ICT investments and to make comparisons between countries are discussed in Ahmed, Schreyer & Wölfl (2004).

[2] The fast development of ICT implies that the labour force must learn, relearn, train, and retrain, i.e. there is a continuous need for households and for entire economies to make specific investments in human capital as long as standardised ICT solutions are not established in each area.

[3] Focusing exclusively on ICT investment products does not fully reflect the benefits of ICT diffusion within investment products or in the economy at large (Papaconstantinou, Sakurai & Wyckoff, 1996).

[4] The EU KLEMS project provides data on ICT capital assets comparable across a number of OECD countries (see www.euklems.net).

increased rapidly. Obviously, the construction of price indices for ICT products is no easy task and a possible source of unreliable results in empirical studies.[5]

There are also other measurement problems involved (Howitt, 1998): (i) many of the knowledge-creating activities are not registered as part of GDP under conventional national accounting, (ii) the contribution of new or improved products to output is typically underestimated, and (iii) the arrival of new technologies makes machines and equipment that were designed for the old one obsolete, and it reduces the value of the skills that workers acquired for the old technology.

However, a time series of investments in ICT in total and in the three major types is not enough to measure the effects of investments in ICT. What is needed is an aggregated, discounted measure of all historic investments in ICT equipment and systems making up the current ICT capital stock[6], or rather of the flow of capital services from the stock of ICT capital. However, normally a strict proportionality between capital services and capital stocks but the ratio can vary between different types of assets. Thus, there is also an aggregation problem.

Starting first with the problem of how to estimate the *ICT capital stock* (or the capital stock of any of the three major types, we assume that there exists a sufficiently long time series of investments in ICT at current prices and a suitable corresponding price index. If we let the current price investment for ICT asset type i in year τ be $I_{t-\tau}^{i}$, and the relevant price index be $p_{t,0}^{i}$, the productive stock of the actual type of ICT asset K_t^i at the beginning of period t can be computed as:

$$K_t^i = \sum_{\tau=0}^{T^i} \left(I_{t-\tau}^i / p_{t,0}^i \right) h_\tau^i R_\tau^i \qquad (2.1)$$

where T^i represents the maximum service life of asset i [7], h_τ^i is an age efficiency function representing the lower efficiency of older vintages of ICT capital goods, and R_τ^i describes the probability of survival of capital goods over a cohort's life span.

[5] For an overview of the problems measuring ICT prices, see Ahmed, Schreyer & Wölfl (2004).
[6] This becomes extra problematic at the sectoral level since ICT equipment might be rented and ICT services out-sourced.
[7] In OECD work the average service life for different types of ICT capital is assumed to be 3 years for software, 7 years for ICT hardware and 15 years for communication equipment (Schreyer, Bignon &

Turning now to the *aggregation* problem, we need a means to effectively incorporate differences in the productive contribution of heterogeneous investments as the composition of investment and capital changes over time. User cost weights provide such a means since, under assumptions of competitive markets and equilibrium conditions, they reflect the marginal productivity of different assets (Jorgensen, 1963; Jorgensen & Griliches, 1967). User costs are imputed prices and reflect how much would be charged in a well-functioning market for a one period-rental of a given capital good. Ignoring tax effects, the user costs of a capital good i, u_t^i, are composed of (i) the net rate of return r_t applied to the purchase price of a new capital good p_t^i, (ii) the costs of depreciation, captured by the rate of depreciation d_t^i, and (iii) the rate of change of the price of the actual capital good expressed by $\psi_t^i \equiv d \ln p_t^i$:

$$u_t^i = p_t^i \left(r_t + d_t^i - \psi_t^i \right) \tag{2.2}$$

The expression in the parenthesis represents the gross rate of return on an investment in a new capital good in year t. The gross rate of return on investments in infrastructure capital goods tends to be higher than for other types of capital goods. This is a result of the rapid obsolescence of ICT capital goods, which enters the user cost of capital in the form of purchase prices of new capital goods and via the rate of depreciation. Falling purchasing prices makes it less expensive to buy new capital goods but raises the costs of holding old capital goods. Depreciation rates may be computed according to different formula but they all shall reflect the relative loss of the value of a capital good due to ageing.

Dupont, 2003). Of course, these assumptions are critical and one can wonder whether the assumed average service lifes might be to long given the rapid technological changes in the field of ICT.

3 The Economic Impact of ICT Diffusion

We have in recent years been able to observe what can be described as an evolutionary process whereby economies at the national and the regional level and all their sectors are being transformed by the rapid development, adoption, and use of ICT innovations. In this respect, ICT functions as a *new generic general purpose technology*, which impacts these economies both broadly and deeply by generating a wide array of new products, production processes and services (Brynjolfsson & Kahin, 2000; Mowery & Simcoe, 2002). Carlsson (2003) takes this idea one step further arguing that ICT, which involve among other things a combination of digitalisation and the Internet, seem to have broader applicability than previous general-purpose technologies. It not only affects all manufacturing industries but also, and even more so, all different service industries, which account for an increasing and dominating share of the economy in developed economies. Furthermore, it has given rise to new industries within both the manufacturing and the service sector. However, one should observe that it is a common feature of new general purpose-technologies that it takes a long time before they are implemented (including the necessary organisational changes) and used in such a way that they could develop their abilities to the fullest (David, 1991).

It is unquestionable that the effects of the development, spread, and use of ICT go much further than changing the industrial composition of developed economies. ICT are playing an increasing role in economic growth, capital investments, and other aspects of the macro-economy (Brynjolfsson & Kahin, 2000). The *emergence of new goods and services* as well as *changes in the characteristics of old goods and services* due to the use of ICT, including the ways good and services are produced and distributed lead to *changes in market structures and competitive conditions* affecting and creating new opportunities for small firms and entrepreneurs. As ICT are routinely deployed in organisations to re-engineer processes, gain *new strategic advantages*, or *network across organisational boundaries*, they change both the internal organisation of companies and other organisations and the relationships between companies and organisations (OECD, 2002). The adoption of ICT allows for a *reduction of transaction costs* and leads possibly to *more efficient markets* (Malone, Yates & Benjamin, 1987; Lee & Clark, 1997).

ICT are a genuine source and generator of new business models and new wealth, but they are also undermining old business models and threatening and even destroying investments and jobs in certain established businesses. In addition, the spread of ICT is changing the labour market by generating *new ICT-occupations* and at the same time changing the requirements for non-ICT jobs. Due to the structural changes generated by ICT, employment is increasing in some sectors and declining in others.

Since the conditions to develop and to use ICT varies substantially between regions, we expect large variations between regions in the timing as well as in the extent that they are affected by ICT.

A common view is that ICT have a large impact on production and business processes and that they thus are a *major stimuli of economic growth*. However, there seems to be substantial disagreement about the form of this impact and researchers in the field seem mostly to use one of two major approaches (Smith, 2002).

The first approach argues that economic growth is driven by the *emergence of new sectors* embodying *new technologies* including the ICT-producing sectors themselves. In this case growth comes from two sources: (i) new sectors exhibit higher growth rates of value added, productivity and incomes and will thus function as a source of growth for the whole economy, and (ii) new sectors change the conditions of other sectors of the economy by changing relative prices, and by providing a new set of inputs that raises productivity either by the introduction of new or improved products or new production methods. The production of ICT and the emergence of new ICT-based industries contribute directly to increase GDP and to boost aggregate productivity.

The second approach argues that, since ICT represent a special type of capital good, increased investments in ICT by companies and governments *will raise labour and total factor productivity.* Investments in ICT complement or replace investments in other capital goods and *increase the capacity of the production of ICT-using sectors and industries.*

However, there is a third potential indirect growth impact – *spillover effects*. When the spillover effects of technological advances from industries producing ICT to industries using ICT takes place, *an increase in total factor productivity* can be achieved (Jorgensen, Ho & Stiroh, 2002; van Ark, 2002). It must be observed that the benefits of investing in and using ICT depend on *sector-specific effects*. ICT are more important to raising productivity in certain sectors than in others and since different countries have different sectoral specialisation, their gains from investing in and using ICT will differ. Investments in and use of *communication network technologies* present a special case because of the benefits derived from spillover and network effects (OECD, 2003; Dederick, Gurbaxani & Kreamer, 2003; Meijers, 2004).

3.1 ICT and Structural Change

Already in the 1980s researchers started to claim that ICT represent a sector and a technology with a potential to generate *structural* change in the world economy, i.e. the expected quantitative effects were large and the expected qualitative effects had the potential to generate a totally new type of economy (Freeman & Perez, 1988). A basic idea here is that economic growth in some sense is related to *qualitative changes* in the sense that the industrial, the occupational, the educational, etc., structure of the economy is changed. It can involve a more advanced division of labour as described by Adam Smith, which allows on the one hand increases in productivity and on the other hand a spin-off and out-sourcing of new activities (Stigler, 1951). Kutznets (1959) stressed that a high rate of growth depends upon a continuous emergence of new inventions and innovations, which provide the basis for new industries whose higher growth rate compensates for the slower growth rates among older industries.

The first to present a more systematic view of innovation as a driver of structural change was Schumpeter and in particular in his book *Business Cycles* from 1939. He does not offer any coherent theory of the generation of innovations but he stresses three points that he sees important:

- Innovations are clustered together and are not evenly distributed in time
- Innovations concentrate in certain sectors and their surroundings
- There are discrepancies between sectors: some industries move on, others stay behind

The historical role of pervasive technologies, such as ICT, has been intensively discussed in the Schumpeterian literature on economic growth and structural change, which started to flourish in the 1970's. This literature presents a framework that explains the subsequent *rise and fall of pervasive technological systems* and their interaction with different sectors in the economy. What this framework suggests is that major *technological breakthroughs, structural change, and economic growth are closely related*, and can only be analysed jointly.

Freeman & Perez (1988) systemizes Schumpeter's work on Kondratieff waves and develops this into an argument that the key driving force of growth at this time is ICT. In their framework, economic growth is driven by *radical technological changes* that shift the entire 'techno-economic' paradigm involving (i) new forms of best-practice organisation, (ii) new skill profiles in the labour force, (iii) new location patterns, (iv) new infrastructures, (v) new consumption patterns, (vi) new types of dominant firms, etc.[8] It is still unclear how these dramatic changes in economic life exactly are related to ICT. However, this approach is often used to create arguments for the role of ICT in modern times. Fagerberg, et al., (2000) argue that what matters for economic growth is the ability to exploit areas of *high technology opportunity,* which in recent decades have been dominated by ICT. Furthermore, they claim that their analysis show that Europe has lost ground in a number of strategically important sectors, particularly those related to ICT.

Verspagen (2004) uses a Schumpeterian framework to make a systematic analysis of the role of ICT in the structural change of the US economy over most of the post-war period. His aim is to relate the role of structural change in connection to a specific historical case of a major technological breakthrough, i.e. ICT. What he shows is that even if ICT have substantial effects on the structure of the economy, one can not draw the conclusion that ICT is the main pervasive technology of our days in generating *technology spillovers* or that it will substitute older technologies completely. The picture is rather that ICT is an *important complement* rather than a substitute to older technologies, which will continue to play an important role in the economy.

[8] It is important to observe that structural changes also are a key feature at the micro scale. ICT redistributes/reallocates work tasks across persons, positions, and operations inside each organisation as well as between organisations. Successful implementation of an ICT project requires reorganisation of the firm around the new technology (Helpman & Trajtenberg, 1998, Yang & Brynjolffson, 2001; Brynjolfsson, Hitt & Yang, 2002).

However, there are many problems associated with this approach and it is open to a number of quite basic objections (Smith, 2002):

1. There is a strong tendency to conflate innovation and diffusion and assuming that radical innovations generate rapid impacts. Technologies, such as ICT, take a long time to diffuse and an even longer time to have an impact.

2. It is not necessary that new sectors contribute to output in a significant way even when they are fully established. Hardware and software ICT industries are still rather small.

3. This approach cannot explain growth in countries that does not possess a substantial ICT producing sector and many of these countries are high growth countries.

3.2 The Effects of ICT on Aggregate Productivity and Output Growth

Analysing economic growth economists have traditionally emphasised the *accumulation* of conventional inputs such as labour and production and infrastructure capital as main force behind output expansion. The basic theoretical background was laid by American economists who from the mid-1950's attempted to isolate the relative contributions of capital investment and technical change to labour productivity growth in the U.S. Solow (1957) was able to demonstrate that the long-run economic growth in the U.S. could not be explained by growth in labour or capital but was instead explained by what Solow termed "*technical change*" that actually was the unexplained residual. To try to disentangle the components of technical change a "growth accounting" research programme was set up in the US (Denison, 1962). The basic *neo-classical approach* applied by Solow and many of his followers consists of a growth equation that relates output to the level of technology – a technology shift parameter – and the inputs of capital and labour. This makes it possible to estimate the extent to which output grows independently of factor inputs, i.e. to estimate "technical change". By quantifying specific inputs, such as *investments in ICT*, it is possible to estimate its role for growth in labour productivity or total factor productivity.

More recently, economists have paid more attention to other growth stimulating factors such as the *sources of technological change* and *institutions*. Following the contributions of Romer (1986 & 1990), Lucas (1988), Grossman & Helpman (1991), and Aghion & Howitt (1992), numerous studies of economic growth place technological change at the heart of the growth process. This change of focus has been stimulated by theoretical achievements, which allow *micro-economic* aspects of the *innovation* process to be linked to macro-economic outcomes.

Many growth analysts have in recent decades tried to estimate the effects of ICT on economic growth. Since ICT represent a GPT, its *growth effects* has been analysed at the *macroeconomic* level as well as at the *sector* level. At the sector level, it is possible to distinguish between studies, which analyse the growth of *ICT producing sectors* and studies, which analyse the effects of the *investments in ICT in other sectors*. In other sectors, the effects of investments in ICT can manifest themselves in terms of higher productivity in firms and sectors that invest intensively in ICT. Investments in ICT should also give higher average rates of returns than alternative types of investment in the economy.

One can identify two major approaches for estimating the *effects of investments in ICT* on economic growth:

1. Estimations of the *productivity effects* of the ICT capital stock based upon quantifications of this capital stock including both hardware and software (Oliner & Sichel, 1994; Sichel, 1997)

2. Estimations of "*technical change*" with a production function approach and relating productivity growth to the use of ICT (Bailey & Gordon, 1988; Jorgensen & Stiroh, 1999).

Before trying to summarize some of the major empirical results, it is important to highlight some of the limitations of the empirical studies (Smith, 2002):

- Basing the econometric estimations on a production function approach implies the assumptions that (i) the economy in question is in some sort of competitive equilibrium, (ii) investment in ICT is rational, and (iii) investments in ICT earn a normal rate of return at the margin.
- The studies normally disregard the possibility that growth can come from other sources but new inputs and new knowledge and technologies embodied in them.
- Most studies concern the US economy, which makes generalisations about the effects of investments in ICT in other countries difficult.
- The studies vary a lot in terms of unit of analysis, performance concepts and measures, input measures and type of econometric analysis, which makes it difficult to compare them (Wilson, 1995).

- Data reliability can often be questioned.

Looking first at the US, the results of the empirical studies seem to have changed over time. Studies covering time-periods up till the early 1990s seldom report any significant impacts of ICT. Franke (1987) in a study of labour productivity in insurance and banking between 1958 and 1983 found declines in capital productivity associated with specific ICT innovations. A study of labour productivity in the service sector by Roach (1991) found large-scale increases in ICT capital stock relative to other capital inputs coupled with stagnant productivity suggesting no payoff from ICT. Morrison & Berndt (1991) and Berndt & Morrison (1995) in a study of labour and total factor productivity in 20 manufacturing industries for the period 1968-1986 found that ICT capital has no impact on productivity compared to non-ICT capital.

Turning to studies that report significant impacts of ICT, we first have Siegel & Griliches (1991), who in a study of US manufacturing found significant impact of ICT on total factor productivity but who also expressed serious doubts over data reliability. Large returns on ICT capital investments and a disappearance of the productivity paradox was found by Brynjolfson & Hitt (1993) in a firm level study of US manufacturing for the period 1987-1991. More recently, a literature has emerged, which more unambiguously has claimed that investments in ICT have driven growth in the US economy since 1995. US productivity growth was at record levels during the period 1995-2000 and so were investments in ICT. Several authors have claimed that this is the long-expected payoff to investments in ICT and lean to the view that ICT have played a significant role in generating a fundamental change in the U.S. economy’s growth (Oliner & Sichel, 2000; Jorgenson & Stiroh, 2000). Despite some methodological differences, these authors derive similar estimates:

i) a high contribution of the ICT sector to growth in labour productivity, ranging from 41 percent to 55 percent;

ii) around a quarter percentage point of the acceleration in labour productivity since 1995 is attributed to ICT (total factor productivity growth in the ICT sector);

iii) industries with the highest investments in ICT also registered the highest increases in labour productivity (cf. Stiroh, 2002b);

iv) along with the ICT-producing industries, ICT-using industries also played a fundamental role in accelerating productivity and growth, with service industries making a particularly important contribution to growth (Triplett & Bosworth, 2002), and ICT contributing a half a percentage point to capital deepening (all of which is attributable to the accumulation of ICT capital). In total, ICT seem to have contributed three-fourth of the labour productivity acceleration between 1995 and 2000 and the ICT-producing and the ICT-using sectors are estimated to have contributed 23 percent and 25 percent, respectively, to American economic growth (Jorgensen, 2001).

Gordon (2000) and Bosworth & Triplett (2000) represent a more critical view and claim that the ICT “revolution” has not had the same impact as the general-purpose technologies introduced in the past century (such as electricity or transportation). However, one should remember that the effects of general-purpose technology revolutions historically seem to generally have occurred in three (often overlapping) main stages. First, technological change raises productivity growth in the innovating sector; second, falling prices encourage capital deepening; and, finally, there can be significant reorganisation of production around the capital goods that embody the new technology. Gordon (2000) focuses on the cyclical component of the US productivity surge, suggesting that half of the acceleration after 1995 was a cyclical phenomenon.

Turning now to studies at the macroeconomic level that include several European and other OECD countries we find that ICT have impacted macroeconomic variables here too, though in many countries on a lesser scale (Mairesse, Cette & Kocoglu, 2000; Daveri, 2002; Jalava & Pohjola, 2002; Coleccia & Schreyer, 2002; COM, 2003). It seems as if the contribution of the growth of ICT capital assets to GDP growth in the OECD countries in principle doubled from the period 1990-1995 to the period 1995-2001 from on average 0.25 to on average 0.50 percentage points (Ahmed, Schreyer & Wölfl, 2004; Jorgenson, 2001, Colecchia & Schreyer, 2001; van Ark, et al., 2003; OECD, 2003). In relative terms, the contribution of ICT capital assets to GDP growth seems to have increased from about 16 percent of total GDP growth to about 20 percent between the two periods. What is intriguing is the *large dispersion* in the contribution of ICT capital assets to economic growth in different OECD countries. Very strong contributions have been observed for the United States, Canada, the Netherlands and Australia amounting to about one fourth of GDP growth over the period 1995-2001. However, for other OECD countries, such as France, Finland, Portugal, and Germany the estimated contribution of ICT capital assets to economic growth is much smaller.

One important reason to the increased contribution of ICT capital assets to economic growth during the second period is the increased importance of ICT capital to growth in total capital input. While non-ICT capital contributed most to capital growth in the period 1990-1995, ICT capital contributed to between one third and half of total capital growth between 1995 and 2001 in most OECD countries (Ahmed, Schreyer & Wölfl, 2004). ICT hardware accounted for the largest share of the contribution of ICT capital to growth in total capital during the 1990s, but ICT software and ICT communications equipment seems to have become increasingly important.

In a panel study of 25 OECD countries, Belorgey, Lecat & Maury (2006) show that both production of and spending on ICT have a positive effect on the labour productivity growth rate. They also find that average spending on ICT 1992-2000, used as a proxy for the contribution made by ICT has a positive effect on the level of labour productivity.

In Europe, in spite of a significant acceleration in investments in and use of ICT between 1998 and 2001, the productivity gains were limited and the disparities between countries wide. According to van Ark (2002), annual labour productivity growth between 1995 and 2000 was only 1.3 percent per year. In recent years, a quarter of EU GDP growth and 40 percent of its labour productivity growth is estimated to be due to investments in ICT, while 60 percent of U.S. productivity growth is explained by these technologies (COM, 2005a). This implies that there within many countries within the European Union is a *potential for catch-up* in terms of investments in ICT capital assets.

What are then the reasons for the divergence between EU and the U.S. in terms of taking advantage of the benefits of investments in ICT? Actually, it is very intriguing that while the consumers in some countries in Western Europe have been quick to adopt new ICT products the overall picture is that Western Europe is lagging behind the US and Japan. Disregarding possible measurement errors, not least concerning the service sector, one explanation is the differences identified in the *sectoral productivity* structure between the two regions. First, the EU is not as highly specialised in ICT-producing sectors as the U.S. Second, ICT-using sectors in the EU have gained lower benefits with regard to total factor productivity growth compared to the same sectors in the U.S. (COM, 2005b). Except for a few small countries, such as Sweden and Finland, manufacturing and service industries in Western Europe have been much less alert at exploiting the potential for new markets and new ways of organizing production and distribution. It has been claimed that the most important difference between the US and Western Europe is that firms in Western Europe have failed to change the way they do business in response to the new technologies (Gordon, 2004). Actually, productivity growth in Western Europe compared to the US seems to have been particularly slow in three main ICT-using service sectors, namely, retail, distribution and financial services (O'Mahony & van Ark, 2003, Eds.). It is quite possible that the extent of market regulation in Western Europe significantly slows the speed of adoption of new technologies and new ways of doing business (Gust & Marquez, 2004). However, it should be noted that labour market regulations differ widely across the countries in Western Europe, which make generalizations difficult.

Van Ark & Piatkowski (2004) investigated the productivity performance of the 10 new EU-members in Eastern Europe (CEE-10) and in EU-15 to detect sources of convergence between the two regions. They show that changes in labour intensity have been an important source of productivity convergence during the 1990s, and assume that it is likely to be so in the near future too. Their study also found that despite lower income levels, ICT capital in the CEE-10 has contributed as much to labour productivity growth as in the EU-15. Analyses of different industries show that manufacturing industries that have invested heavily in ICT have been a key factor in the restructuring process. As such ICT may therefore have been an important source of growth but probably a temporary source of convergence. In the longer run the impact of ICT on growth will have to come primarily from its productive use in services. The paper also includes a New Economy Indicator that reflects the existence of an economic environment conducive for continued investments in and use of ICT. It shows that further reforms are much needed for CEE countries to enter a second convergence phase in the coming decades.

3.3 The Effects of ICT on Productivity and Output Growth at Firm Level

There is a lack of empirical evidence about the relationship between investments in and use of ICT and productivity and output growth outside the U.S., mainly due to a lack of internationally comparable estimates of investments in and use of ICT capital at this level (van Ark, 2002; Devaraj & Kohli, 2000; Crowston & Myers, 2004). Much clearer and stronger evidence of the impacts of ICT comes from evidence at the firm (company) level (Bryjolfsson & Hitt, 1996; Baily & Solow, 2001; Brynjolfson, Hitt & Yang, 2002; Bresnahan, Brynjolfson & Hitt, 2002; COM, 2003; OECD, 2003; Kohli & Devaraj, 2003). While spillovers from ICT are typically not found at industry level (Stiroh, 2002 & 2003), there exist firm-level evidence that ICT in the US has a larger impact on productivity than suggested by its share of total costs (Brynjolfsson & Hitt, 2000 & 2003; OECD, 2004)

At the firm level, ICT influence production in several ways. First of all they enter production embodied in capital goods with their pertinent software (Jorgensen, 2001) which promote productivity not only by reducing production costs but, above all, improving the quality, the flexibility, the reliability, and so on, of processes and products. Second, the new capital goods make it possible to produce new types of goods and in particular new types of services. Third, ICT components make it possible to improve the quality of existing products as well as developing totally new products that are more highly valued by customers. An important element over time is the rapidly increasing capacity of ICT capital goods and components at the same time as their costs have decreased continuously.

The use of ICT in the production process increases labour productivity not only through automation and the transfer of tasks to customers, but also through capital deepening. As coordination technologies, ICT generate major impacts on firms because they allow for a more efficient use of information, which increases efficiency as well as give rise to synergies. The introduction of ICT improves the access to information within firms, thus enabling more effective and more rapid decision-making by employees and managers (OECD, 2003; Dederick, Gurbaxani & Kraemer, 2003). As firms have introduced ICT, they have also in a parallel process or as a result of the introduction of ICT changed their internal organisation, among other things to make the organisation more flexible. Flexibility has been enhanced by self-manged teams, multi-tasking, just-in-time production and delivery, total-quality management, and decentralised decision-making (Aubert, Caroli & Roger, 2006). A number of studies show that ICT and changes of the internal organisation of firms have significant positive effects on labour productivity (Black & Lynch, 2001; Brynjolfsson & Hitt, 2000; Bresnahan, Brynjolfsson & Hitt, 2002).[9] In particular, it seems as if it is through their role as coordination technologies that ICT have a special impact on total factor productivity at the firm level (Brynjolfson & Hitt, 2000; Brynjolfson, Hitt & Yang, 2002; Dedrick, Gurbaxani & Kraemer, 2003).

With regard to the impact on the production process as a whole, the use of ICT improves the competitiveness of firms making it possible for them to increase their market share by becoming leaner than their competitors. The use of ICT also helps firms to expand their product ranges, customise the services they offer and/or respond better and quicker to customer demand. The use of ICT also makes it much easier for firms to *outsource* and even *offshore* many of its activities and instead concentrating on its core business and core competence. There are substantial evidences that disparities in aggregate productivity growth are mainly due to differences in performance at the industry and also at the firm level including the entry of high performing new firms (Cohen, Garibaldi & Scarpetta, 2004).

Results obtained in recent years show that while investments in ICT are necessary, they are not sufficient to guarantee that firms will achieve full productivity benefits (Lera-López & Billón-Currás, 2005). Full effects of investments in ICT in terms of use of ICT will be achieved only when accompanied by complementary capital investments, investments in human capital, changes in the organisation of firms and production systems, development of improved and new goods and services, and so on. However, changes within existing firms are not enough to get the full productivity benefits from investments in ICT. Of critical importance is also the institutional framework within which firms operate, which determines the conditions for investments and competition as well as for innovation and entrepreneurship. Lack of competition within service sector industries within the EU due to too-long remaining national regulations and protection is most probably one major reason why these

[9] Bertschek & Kaiser (2004) criticize these studies for assuming that increases in labour productivity induce an internal reorganisation of firms. They present empirical evidence, which indicates that labour productivity and the internal reorganisation of firms are simultaneously determined.

industries within the EU has been lagging in terms of innovation and productivity compared to the same industries in the US. Looking at the regional level within the EU it is obvious that there are substantial variations in terms of formal institutions (laws, regulations, collective agreements, etc.)[10] as well as in informal institutions (norms, cultures, traditions, customs, practices, etc.), which influences the propensity to invest and adopt ICT as well as the effects of the diffusion of ICT.

[10] Informal institutions are part of the wider concept "social capital" (Westlund, 2006). Obviously, regional variations in social capital have an influence ICT investments and the effects of ICT investments.

4 Regional Dynamics and Economic Transformations During the Deployment Phase of ICT

During recent decades, production and innovation systems have going through radical but simultaneous and interwoven transformations due to new competitive strategies, globalisation, the emergence of the knowledge society and the ICT revolution. This has created quite new conditions for the business community as well as for the political community. However, the *geographical impacts* of these developments in general and of the ICT revolution in particular have been disputed. Some argue that we are heading for a world where businesses operate without considerations of supra-regional, national, and regional boundaries, where multinational companies act without any distinct home base and where ICT including the use of E-commerce and the Internet exclude time and space as important parameters. Others claim that geographical proximity increase in importance to businesses in order to be able to create inter-firm networks based on trust, reciprocity, and interactive learning. As we will try to show below, both stories are true to a certain extent and both processes are running simultaneously and in intense interaction with each other.

In most advanced economies, an ever increasing share of economic inputs and outputs is in the form of ICT and knowledge (Bristow, 2003). As a result, the traditional determinants of *industrial location* – access to raw materials, transportation networks, low costs, a large pool of general labour – are becoming less important for location within these economies. Instead, *locational choice is increasingly becoming governed by access to particular skills, technology, and knowledge, as well as entrepreneurial talent and venture capital.* Of particular importance is the provision of ICT skills, ICT technology, ICT knowledge, ICT services, ICT entrepreneurial talent, and ICT competent venture capital (Johansson, 2006).

Although, there is now a substantial body of literature on the spatial consequences of the increased use of ICT in the economy, much of it is inconclusive (Johansson, Karlsson & Stough, 2006). One reason might be that the context is rapidly changing not least due to the success of the Internet and e-commerce. Even if much interest have been devoted to the issue of how investments in ICT capital and the use of ICT induce *spatial transformations,* much less interest have been devoted to how these transformations affect regional economic growth. This is interesting per se since several economists have suggested an important link between national economic growth and the concentration of people and firms in large urban regions (Karlsson & Johansson, 2006). The high concentration of people and firms in large urban regions creates an environment in which knowledge moves quickly from person to person and from firm to firm. This implies that large, dense locations encourage *knowledge diffusion* and exchange, thus facilitating the spread of new knowledge that underlies the creation and imitation of new products and new ways to produce products (Carlino, 2001).

The New Economic Geography (NEG) theory, which has developed since the early 1990s, provides theoretical tools to understand the *factors driving spatial transformations and the effects of these transformations on regional economic growth*. It starts with the presumption that *functional regions* and not countries are the natural units for economic analysis. The reason is that economic activities are not evenly distributed across space and show clear tendencies to agglomerate. The NEG theory explains why economic activities concentrate in certain regions and not in others (Krugman, 1991; Fujita, Krugman & Venables, 1999; Johansson, Karlsson & Stough, 2002, Eds.)

The increased use of ICT enables major *reductions in geographical transaction costs* by reducing spatial information frictions (Flamm, 1999; Sichel, 1997). Examining the interrelationships between three variables – increasing returns due to scale economies, demand for final products and geographical transaction costs – in a world with monopolistic competition makes it possible to draw some general analytical conclusions concerning the effects ICT-induced reductions of geographical transaction costs. When geographical transaction costs are reduced, producers in large regions, i.e. regions with large home markets, which already have good opportunities to exploit economies of scale due to a large home market, can lower the production costs by also delivering to other regions, i.e. by increasing their exports. When exports increase, there will also be increases in incomes, which induce more producers of differentiated products to start production in the large region. Increased exports also imply an increased demand for differentiated inputs, which will induce more producers with their internal scale economies to start producing such inputs. As a consequence, we have a situation with cumulative causation or positive feed-backs initiated by the effects of ICT on geographical transaction costs. Thus, as first conclusion we may assume that *investments in ICT and particular in communications equipment stimulate further agglomeration*.

The original Krugman version of the NEG theory has nothing to say about the role of knowledge in regional economic growth. Increasing returns is the result of the exploitation of economics of scale in production only. However, since the development and exploitation of ICT is intimately associated with the development, diffusion, appropriation and use of knowledge it is necessary to integrate knowledge and knowledge externalities in the above framework. The *literature on innovation systems* strongly indicates that *knowledge flows, including spillovers are at the core of regional development* (Karlsson & Johansson, 2006). Since knowledge sources have been found to be geographically concentrated (Audretsch & Feldman, 1996), location is crucial in understanding knowledge flows (Karlsson & Andersson, 2007; Andersson, Gråsjö & Karlsson, 2007). In addition, the capacity to absorb flows of new knowledge is facilitated by geographical proximity (Jaffe, Trajtenberg & Henderson, 1993; Baptista & Swann, 1998). Already Marshall (1920) identified the exchange of ideas as a type of externality leading to localisation, i.e. clustering, of economic activities.

Large, dense regions offer special advantages in terms of knowledge flows and knowledge spillovers, since they combine the localisation of clusters in specific industries with industrial diversity, i.e. with a range of different industrial clusters. This suggests a formulation of a NEG model based upon knowledge externalities. When a (large) functional region has achieved an initial advantage in knowledge production due to e.g. a large pool of well-educated labour and a rich supply of ICT capital assets, it will attract (i) knowledge-creating and knowledge-utilising firms, since it offers opportunities to take advantage of increasing returns in knowledge production and knowledge use including imitation, and (ii) knowledge-rich labour, which wants to take advantage of the increasing demand for its skills. With increased knowledge intensity in larger regions we can expect increased investments in ICT capital assets, which will further reduce geographical transaction costs.

4.1 ICT and Spatial Transformations

The claim above that the interaction between knowledge and ICT will stimulate further agglomeration clashes with the predictions of some cyber prophets and technological optimists. They have claimed that the emergence of the digital economy would kill distance and make urban regions superfluous (Friedman, 2005; Cairncross, 1997; Knoke, 1996; Naisbit, 1995; Negroponte, 1995; Toffler, 1980), and at the same time eliminating the scale disadvantages of smaller and more peripheral regions. Their basic idea was that the spread of the use of ICT has the potential to replace face-to-face activities, i.e. to substitute physical movements that formerly occurred in central locations, which would strongly reduce or even eliminate agglomeration economies and hence make all economic activities totally "foot-loose". These deterministic views see developments and investments in ICT as radically reshaping society, and by extension, cities.

However, the difficulties in forecasting the future spatial and social impact of ICT is illustrated by Salomon (1998), who demonstrates the *complexity* by reviewing the case of telecommuting as a travel substitute. In his study, he stresses that technologies are social constructs and thus, in order to forecast the impact of such technologies, the way the individual decision-maker penetrates such a technology must be understood, as well as the extent to which individuals (and firms) adopt it and change their behaviour accordingly. Nevertheless, *the relationship between transport technology and ICT* has received much interest in recent decades (Salomon, 1986; Nilles, 1988; Mokhtarian, 1991; Hepworth & Ducatel, 1992; Mokhtarian & Salomon, 2001). There are many obvious reasons for this. Both technologies belong to the class of "friction-reducing technologies", both have a network structure, and there is, in some cases, a (probably overstated) potential for substitution between physical travel and virtual travel. As both technologies facilitate remote activities, there has been much interest in this potential substitution (Garrison & Deakin, 1988; Boghani, Kimble & Spencer, 1991). However, Mokhtarian & Meenaksisundaran (1999) remind us that alongside substitution effects between transportation and ICT, there is considerable evidence suggesting stimulation or generation effects as well, i.e. ICT can stimulate more physical travel and transport. Moreover, ICT can change travel and transport behaviour, not just the decision about the travel or the transport itself. ICT also offer tools to increase the quality of transportation networks and services.

In the literature, it is argued that *ICT open new complementarities and potential synergies*, which are most evident in the way ICT networks are becoming integral to an increasing array of traffic and transport operations (Giannopoulus & Gillespie, 1993, Eds.; Nijkamp, Pepping & Banister, 1995). Through better monitoring with the help of ICT, a better, faster, and timelier flow of goods and persons from their origin to their place of destination can in principle be realised. ICT is in this sense first and foremost a complementary technology to existing distribution and transportation networks. While the term e-commerce seems to imply a process of substitution of physical commerce, ICT is rather likely to increase the efficiency of the distribution and transport delivery systems through reduction in transport costs and better usage of transport infrastructure whether by ship, rail, road, or air transport. Substitution might occur but rather between different, alternative transport infrastructure systems (Soete, 2006).

Today it seems clear that the “death of distance” picture is at least single-sided. As ICT have been adopted for decades (and if we include the telephone for more than a century), most researchers today seem convinced that cities are not going to disappear (Cohen-Blankshtain & Nijkamp, 2004). Graham and Marvin (2000) stress that most *applications of ICT are largely metropolitan phenomena* and that ICT and large metropolitan are mutually supportive phenomena. Not least, the development of new technologies and new products seems likely to remain grounded in the large urban regions in the advanced countries, which imply that these regions will keep their locational attractiveness. There is also increasing evidence that *increased investments in and use of ICT actually reinforces the position of large cities* and not least the leading urban regions (Castells, 1989 & 1996; Moss, 1991; Hall, 1998; Wheeler, Aoyama & Warf, 2000, Eds.). Kolko (1999) suggests that ICT have led to the “death of distance”, but not to the “death of cities”. However, Graham (2002) claims that both distance and cities are far from being dead, and that *geography still matters* (cf. Nijkamp, Linders & de Groot, 2002). Beyers (2000) accentuates that ICT may enable living far from the city, but he also argues that not only are many businesses in the information society strongly tied to localised markets, but it is also in urban areas that the people working in these sectors want to live, for reasons related to consumption and tastes, and dictated by spousal relationships and other social relationships.

Bellini et al (2003) examine the impact of ICT on the location patterns of industries in Italy and find evidence for increasing convergence of industrial structure across regions in line with the "death of distance" hypothesis. However, they also find that knowledge-intensive industries tend to cluster together suggesting that knowledge-intensity acts as a counterbalancing force to the dispersion effect of ICT.

Investments in ICT may not necessarily encourage the dispersion of economic activities due to the network and technology effects of the supply of ICT infrastructure (Ogawa, 2000). Grant & Bergiust (2000) argue that ICT networks will play the same role in the twenty-first century that streets and highways played in the twentieth century, since they both are "spatial technologies" (Couclelis, 1994). Just as the car affected the shape of urban regions, there is an expectation that ICT will change the cities. The "information highway" now inherits the role of physical highways. Therefore, while transport was the "maker and breaker of cities" (Clark, 1957), ICT are now expected to inherit or share this role.

Already in the early 1990s, Goddard (1991) developed a conceptual model to assess the possible effects of investments in ICT on the urban form, which emphasizes the *effects of ICT on organisations*. He identifies three levels of analysis that are needed to evaluate the expected future effects: (i) the effects on the organisational level, (ii) the effects on infrastructure, and (iii) the effects on different sectors. Often much of the research about the effects of ICT on the urban form is concentrated on one single channel of research. In most cases there is no aggregate analysis that examines the overall and interrelated effects of these technologies on the city on the whole (and on the system of cities). Thus, the empirical evidences are eclectic and there is still no integrated picture of foreseeable changes.

The large urban regions in the advanced countries are concentrations of knowledge – human capital, universities and R&D activities – and *knowledge constitutes a critical input for productivity, economic growth and development*. These regions are also leading centres of innovation and imitation. Desrochers (1997) points out the importance of geographical location for the transmission of tacit knowledge and innovations between competitors, suppliers, and customers via face-to-face interactions. Cities are a means of reducing the fixed travel costs involved in face-to-face interactions. Even if in principle improvements in ICT could eliminate the demand for face-to-face interactions and make cities obsolete in this respect, empirical results point in the direction that the use of mediated contacts is mainly a complement to face-to-face interactions (Gaspar & Glaeser, 1998). The conclusion is that as ICT improve, the demand for interactions of all varieties, including face-to-face interactions, should rise. Furthermore, these regions are the home for new propulsive and emergent growth sectors such as tourism and cultural industries based upon face-to-face interaction (Andersson & Andersson, 2006).

It should in this context be observed that *the provision of network infrastructures vary substantially* making only certain locations viable for communication intensive organisations and activities. Thus, it should be no surprise that the majority of the firms in the Internet industry is concentrated in key metropolitan regions (Bristow, 2003; Zook, 2002) and that the same general pattern prevails for both the so-called Internet ‘backbones’ in the United States (Malecki & Gorman, 2001) and the multimedia industry. Interestingly, Zook (2000) shows that over time there seems to be a stronger connection between Internet content and the information-intensive industries than between Internet content and the industries providing the computer and telecommunications technology necessary or the Internet to operate. Even if these agglomerations interact digitally over long distance, their existence does not suggest a geography of general dispersion or that the industries in question should be indifferent to distance or proximity (Leamer & Storper, 2001). On the contrary, these industries are heavily concentrated in existing large agglomerations, thereby at least in the short run reinforcing existing patterns of uneven development.

4.2 ICT and the Location of Firms

Over time, we expect ICT to affect *patterns of concentration and convergence of industries*. Concentration is the tendency of an industry to cluster geographically, while convergence is the tendency of an industry to become more uniformly distributed geographically. Traxler & Luger (2000) illustrate the complicated and multidimensional *effects of ICT on firm location*. In their study, they examined possible spatial effects of these new technologies on the location of firms and concluded that ICT can have two opposite effects: *dispersion and reinforcement of concentration*. Indeed a relatively large body of literature comes up with such contradictory conclusions about the expected effects of ICT, emphasising the complex effects of these technologies on the behaviour of people. Kolko (2002) found that ICT intensive industries exhibit slower convergence, i.e. deconcentration, than other industries. This result indicate that *clusters of ICT intensive industries persist not because they are ICT intensive per se, but because they tend to rely on highly skilled labour*.

However, the effects of ICT go much further than to the ICT intensive industries. Investments in and the use of ICT have had a very strong effect on trends, that started well before the general diffusion of ICT. In recent decades, we have witnessed a gradual denationalisation of in particular large companies. Internationalisation and globalisation of production and markets have created the preconditions for *locational choices based upon global rather than national considerations*. The possibilities for companies to move their activities within and between countries have increased considerably. A clear tendency is that company units and plants are located where the conditions are the best whether we are talking about R&D or the production of standardised components. It is in particular two technological conditions, which have made the new scenarios possible. They are *production decomposition* and *network control*. Production decomposition implies that the production of a certain product can be divided into separate stages that take place in different production units. To keep such a production system running there is a need for network control.

These new scenarios involve increased outsourcing as well as increased off-shoring of production. Famous historical examples of this is the production of semi-conductors where production is globally decomposed and involves multiple locations in several countries and the value chain controlled in an integrated way, often by multinational enterprises but also the production of products, such as mobile phones, computers, cars and airplanes. The degree of off-shoring is among other things a function of how easy it is to decompose a production process into different stages, and the labour-intensity of the intermediate production steps (Grunwald & Flamm, 1985) While outsourcing and off-shoring of production has been present in several decades, what is much more recent is the outsourcing and, in particular, the off-shoring of service production, which have become possible due to technological advances in ICT, declining real prices of ICT, large investments in ICT network infrastructures, e.g. broadband and mobile phone networks, rapid increases of telecommunication connections, including broadband connections, and decreased costs for air travelling (Kirkegaard, 2004b). These developments have made services increasingly tradeable (ICT-enabled services) and reduced the constraints on the choice of location for the production of services (Friedman, 2005; Abramovsky & Griffith, 2005).

Technical progress has reduced the optimal scale for a large number of economic activities. This implies that many small production units can replace a large production unit without efficiency and productivity losses. Thus, it has become possible to divide the production of goods and services between several or even many separated, local production and control units. In this case production is decomposed in a production chain, where several, separated production units each produces different components, while others take care of assembly, distribution and administration. However, a precondition is that production and flows of goods are controlled by means of ICT applications.

The degrees of freedom regarding the choice of location have increased manifold due to improvements and cost reductions within freight transportation, air travelling and ICT. The use of ICT and, in particular, the Internet makes it possible for companies to have *frequent interactions with suppliers, customers and their own production units* without daily face-to-face interaction, as long as the interactions concern routine contacts and standardised, well co-ordinated information flows.

4.3 ICT and Regional Economic Growth

Having discussed the relationship between ICT and regional transformations above it is now time to turn to the relationship between ICT and regional economic growth. One of the most stylized facts about economic growth is that productivity growth, rather than factor accumulation, accounts for most of the growth differentials across countries. Easterly & Levine (2001) argue that in the search for the secrets of long-run economic growth, a high priority should go to rigorously defining total factor productivity (TFP), empirically dissecting it, and identifying the policies and institutions most conducive to its growth. Even if the inflow of labour can play a somewhat larger role for economic growth at the regional than at the national level, we have strong reasons to belive that the major effect of ICT on economic growth goes via its effect on TFP in ICT-producing as well as ICT-using industries.

However, the development of ICT as well as the application of ICT seem to be critically dependent upon the availability of human capital in general and human capital with ICT-competence, in particular. We can look upon ICT and human capital as complementary factors, Hence, we start our discussion of the relationship between ICT and regional economic growth from a theoretical perspective according to which the underlying source of sustained growth in per capita income, namely the *accumulation of knowledge is endogenised* through formal education, on-the-job training, basic and applied research, learning-by-doing, and process and product innovations (Aghion & Howitt, 1992), which implies that the indigenous innovative activities of regions become critical. This approach fully incorporates the *Schumpeterian view of innovation* as a result of deliberate efforts. New knowledge is not pure public goods, since even if it is non-rivalrous it is at least partly excludable. It is produced using existing knowledge and human capital through investments in R&D, which are re-numerated by the temporary extra rent provided by the (partial and at least temporary) appropriability of the results of innovation in markets characterised by monopolistic competition (Romer, 1990; Grossman & Helpman, 1991). However, the existing accessible pool of knowledge increases because the benefits of generating new knowledge are not fully appropriated by the innovating firm due to knowledge spillovers, which benefits other firms in their innovative activities.

Knowledge is a special type of "product", since it is not exhausted after use. Instead, it is cumulative by being based on the existing pool of knowledge.

This theoretical perspective, which includes innovative efforts into the determinants of growth, allows for permanent disparities in regional growth rates. Regions that are *well-endowed in terms of knowledge and capital, due to their accumulated pool of knowledge will have a continuous advantage over regions less well endowed*. The reason is that knowledge consists of organised or structured information that is difficult to codify and interpret, generally due to its intrinsic indivisibility (Karlsson & Johansson, 2006). As a consequence, knowledge is difficult to transfer without direct face-to-face interaction. This implies that *proximity matters for knowledge transfer*. Thus, knowledge flows much faster within than between regions. Even if ICT to a certain extent may change the conditions for knowledge flows, it is by no means given that this helps the less well-endowed regions. One can argue that *the more well-endowed regions are in a better position to take advantage of the possibilities offered by ICT*.

In a context like this, it is crucial to understand how knowledge is transferred between as well as within regions as well as among the actors involved. How is knowledge transferred between its source and its potential users? Starting with *inter-regional knowledge transfers* it is obvious that *multinational firms play a critical role*. Their intra-firm knowledge networks that also include the mobility of staff between different regions provide major links for knowledge transfers. Besides these links, embodied knowledge, which is the most critical part of knowledge, is transferred mainly via the mobility of knowledgeable people and capital goods including software. Turning to *intra-regional knowledge transfers* much evidence points in the direction the mobility of knowledgeable people and direct face-to-face interaction between such people are the most important channels for intra-regional knowledge transfers.

With *knowledge spillovers* given such a central role in the growth process, it is natural to ask which regional economic milieus are most conducive to knowledge spillovers? Does the specific mix of economic activities undertaken within any particular region matter (Feldman & Audretsch, 1999)? Glaeser, et al. (1992) consider the factors that influence innovative activities in urban regions, and identify two relevant models in the economics literature. The first model, the so-called *Marshall-Arrow-Romer* model formalises the insight that *the concentration of a particular industry within a specific urban region* (Lösch, 1954) *promotes intra-regional knowledge spillovers across firms and therefore stimulates innovation in that particular industry*. The basic assumption here is that knowledge spillovers mainly take place across firms within the same industry.

The second model regards *inter-industry spillovers* as the most important source of new knowledge. Specifically, Jacobs (1969) argues that the *agglomeration of firms in urban regions fosters innovation due to the diversity of knowledge sources located in such regions*. Thus, the variety of industries within an urban region can be a powerful engine of growth for that region, and the exchange of complementary knowledge across diverse firms and economic agents leads to increasing returns to new knowledge.

Given the relative importance of the two specialisation mechanisms, *different regions may exhibit different growth experiences given their historically given economic structure*. Given that ICT represent a general purpose technology and that the development of ICT is strongly concentrated to a limited number of urban regions a critical question is to what extent different regions offer good opportunities for knowledge related to ICT and the use of ICT to penetrate ICT-using sectors and industries, which in principle are all sectors and all industries represented?

Obviously, there are several factors that have to be accounted for to understand the regional growth, since regions have different capabilities to absorb and to transform accessible knowledge into (endogenous) economic growth (Crescenzi, 2005). It seems, for example, that *the ability of regions to adopt and to adapt new technologies depends on the institutional infrastructure, education, geography, and resources devoted to R&D* (Maurseth & Verspagen, 1999). These and other factors that influence innovation form a system of innovation, i.e. *the network of institutions in the public and the private sector whose activities and interactions initiate, import, modify, and diffuse new technologies* (Freeman, 1987). The systems approach is not a theory but a focusing device for identifying factors relevant for the innovation process (Edquist, 1997). Systems of innovation can be identified at the national level (Lundvall, 1992) but here we concentrate on *regional systems of innovation*

(Andersson & Karlsson, 2006; Andersson & Karlsson, 2004), which exist as self-consistent and self-organised systems within the national ones (Howells, 1999).

Regional innovation systems can be seen as key building blocks and *the engine in the innovative process*. The process of innovation is still in a general sense governed by the national system of innovation but it is localised and embedded in a regional innovation system. These regional innovation systems should be understood in terms of relationships and interactions between the various economic actors that make up the innovation system (Cooke, 1997), i.e. the innovative milieu (Camagni, 1995), where probably most actors are located in the region in question but others located in other regions nationally as well as abroad and integrated via various forms of network configurations.

Trying to understand the role of ICT for regional growth it is also important to acknowledge that ICT is nothing constant but instead in continuous change. Being a general purpose technology it changes over time as a result of scientific and technological advances, which increases its potential applications as well as reduces its costs, but also due to changes in the selection environment, which contribute to determine the timing and type of uses of the new technology. The selection environment is made up by all non-technological factors such as markets, supply of labour with the relevant training, infrastructure investments, institutional factors, and government regulation that to a varying degree affect the R&D carried out in the field, the kind of innovations launched and the speed of adoption of these innovations. However, despite powerful influences from the selection environment, ICT has rules and a momentum of its own, which determine the direction of how the technology develops. This implies that certain regions that have specialised in certain types of ICT might find that they are on the wrong trajectory as technology continuous to develop. The specialisation in mainframe and mini-computers in certain regions are obvious examples.

The effect of ICT on regional economic growth does come from two sources: the involvement of each region in ICT production and the speed of adoption of ICT in each region. Since, the involvement of different regions in the development and production of ICT as well as their selection environments for the adoption of ICT differ a lot, we shall naturally expect different effects of the diffusion of ICT on economic growth in different regions.

The extent to which different regions are involved in ICT production depends among other things upon historical initiatives by industry and/or national and/or regional governments and the past success of these initiatives. In those regions where the right conditions have prevailed ICT producing clusters have emerged based upon innovation, imitation and often the development of backward and/or forward linkages. Not least has technological imitation within different ICT industries played an important role in many successful ICT clusters, since such imitation is coupled with further technological innovation both by the imitating firms and by those firms whose innovations are subject to imitation. A critical factor for such dynamic processes to evolve is of course that knowledge to a substantial degree can spillover between the firms involved.

Technological imitation stands for the inter-firm diffusion of innovations, i.e. for what might be called production or supply-side diffusion of innovations. The speed of inter-firm diffusion and the path of investments in production capacity by the firms in the industry is one factor determining regional economic growth. To the extent that the region is the market for the innovation the capacity growth and the competition between the suppliers will be one of the factors determining the speed by which the innovation is diffused in the region.

In terms of ICT production it seems as if regions can take advantage of ICT without being producers of ICT hardware, i.e. production of ICT hardware is not a necessary condition for ICT to have an effect on regional economic growth. Probably, the same prevails for ICT software in many cases. Furthermore, investments in ICT network infrastructure by different regions play an important role for the regional growth effects of ICT. However, due to the network structure of ICT infrastructures effects of investments in ICT infrastructure in one region may benefit other regions as well.

General purpose technologies, such as ICT undergo uncountable transformations over time. Naturally, suppliers invest resources to provide successively better and better versions of the products embodying ICT. These ongoing innovative activities within the ICT sector are yielding series of incremental improvements in existing ICT products at the same time as totally new ICT-products are developed. On the user side and here we focus on firms as users of ICT a similar process proceeds because as each user firm use a new piece of ICT to its production process or as an input in its products, it tends to make qualitative and quantitative changes in equipment, and to refine or add new features to its products as well as develop new products. Thus, ICT is used for product and process development in different user industries, in principle, in all industries including the ICT industry itself. Product and process development may involve the introduction of totally new products and processes, respectively, as well s the renewal of old products and processes. In terms of traditional production theory, product and process development based upon ICT give rise to new production functions.

Product and process development based upon ICT must be seen as part of the competitive strategy for a firm in a given industry. Every firm within an industry occupies a specific place in the competitive spectrum. Its strengths and weaknesses with respect to particular products, to particular markets or vis-à-vis particular competitors will influence its choice of competitive strategies. Actually, product and process develop, together with sales or market promotion can be viewed as the major instruments for firms in the competitive struggle. In this competition, firms have three major strategic options: i) innovative competition based upon product development, ii) price or cost competition based upon process development, and iii) marketing competition based upon sales or market promotion. From a regional point of view it is obvious that the growth effect of ICT is much dependent upon the ability and the willingness of the firms in the region to adopt and implement ICT as a strategic competitive tool.

The potential of firms to use ICT to develop new products is depending upon the accessible market potential in different regions. The total market potential of a region consists of its own market potential and the accessible market potential in other regions. How accessible markets in other regions are depends upon the geographical transaction costs of different products. Obviously, firms in larger regions have an advantage when it comes to develop new ICT-using products due to a larger market potential – the home market effect. The potentials of smaller regions mainly are to be found in hardware and possibly software production given that they fully can take advantage of location economies by developing strong enough clusters. Another niche for smaller regions given that their ICT network infrastructure is good enough is to specialise on different types of call-centre activities. However, the development and supply of more advanced ICT-based services seems mainly to be a prerogative for larger regions, which have a large enough supply of qualified labour and a large enough supply of qualified customers, since the development and the supply of such services is critically dependent upon often frequent face-to-face interaction.

The adoption of innovations by firms at the regional level is on the one hand dependent upon their characteristics and on the other hand on the regional selection environment including the regional economic milieu offered by the actual region. Important firm characteristics are: i) size of firms, ii) economic and financial characteristics of firms, iii) the human capital characteristics of firms including the characteristics of their management, and iv) the internal and external communication networks of firms. The regional economic milieu is made up by among other things i) accessibility to regional and interregional market potential, ii) availability of production factors, and in particular, regionally "trapped" factors, such as accessibility to educated labour, iii) the existence of external economies of scale in the form of localisation and urbanisation economies, and iv) the institutional framework including regional policies to stimulate innovation and innovation adoption as well as the social capital in the region. This implies that transport and ICT infrastructure is important since they are factors determining the prevailing accessibilities.

It is important to observe that there exists an optimal rate of innovation adoption and innovation diffusion, which implies that all new innovations should not be adopted immediately by all potential user firms. Due to the fact that many firms recently have adopted earlier varieties of ICT inputs for their products and/or ICT capital goods for their production processes, it is quite rational for them not to adopt every new potentially useful innovation immediately. Due to their recent investments these firms have a sunk-cost advantage of postponing an adoption until the sunk-cost advantage has vanished. This implies that regional policies aiming at stimulating the adoption of ICT innovations to stimulate regional economic growth must consider what is rational from the potential user firms' point of view.

Of course, there can exist and probably exist various market failures that might motivate certain regional policy initiatives to stimulate the adoption of ICT innovations by firms. One might here mention lack of information about new ICT innovations and their potential, lack of labour with the right ICT qualifications, the existence of unexploited positive external economies including learning economies, lack of ICT network infrastructure, etc. However, it is important also to consider the potential problems and costs of regional ICT policy in terms of the long time lags involved before policies have effects, the existence of asymmetric information, the lack of detailed information and knowledge about ICT among policy makers, the existence of vested interest in industry as well as among policy makers, the risks of distorting the function of markets, etc. Given this situation the best regional ICT policy to stimulate regional economic growth may in many cases be rather to improve the general economic milieu in the region in terms of transport and ICT network infrastructure, regional institutions and higher education including ICT education than to try to directly influence the ICT adoption decisions by firms.

5 Regional Innovation Systems and the Layers of Innovation

5. 1 Regional Innovation Systems: Key Characteristics and Dimensions

In the past decade the innovation system (IS) approach has substantially enhanced our understanding of the nature of the innovation process, highlighting that innovation is an evolutionary, non-linear and interactive endeavour that requires intensive cooperation between firms and other organisations (Edquist 1997, 2005). Furthermore, ispired by the institutionalist school of thought (Hodgson 1988, 1999), the IS literature emphasises the impact of formal (laws, rules, etc.) and informal institutions (habits, routines, established practices, etc.) on innovation activities (Nelson and Winter 1982; Johnson 1992; Edquist and Johnson 1997; Edquist 2005).

Initially, the concept of innovation systems has been applied to the national level (Lundvall 1992; Nelson 1993; OECD 1999; Groenewegen and van der Steen 2006; Lundvall 2007)[11]. The literature on national innovation systems (NIS) has shown that countries differ enormously with respect to their economic structures, R&D bases, institutional set-ups and, consequently, innovation performances (Edquist 2001). Nations, however, can exhibit huge disparities in innovation across regions. This insight has provoked a growing interest by academic scholars in regional innovation systems (RIS)[12]. There are several reasons underscoring the relevance of the regional level as an adequate unit of analysis for studying innovation. First, there are marked differences between regions regarding their pattern of industrial specialisation and innovation performance (Howells 1999; Breschi 2000; Paci and Usai 2000, Hollanders 2007). Second, knowledge spillovers, which are ascribed to play a crucial role in the innovation process, are often spatially bounded (Jaffe 1989; Jaffe et al. 1993; Audretsch and Feldman 1996; Anselin et al. 1997; Bottazzi and Peri 2003). Third, notwithstanding increasing codification tendencies of knowledge (David and

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[11] In the 1990s also “non-territorial” specifications of innovation systems emerged, including technological innovation systems (Carlsson 1994) and sectoral innovation systems (Breschi and Malerba 1997; Malerba 2002). The scholars favouring the technological approach argue that systemic interrelationships are unique to technology fields. The protagonists of the sectoral approach examine how groups of firms develop and manufacture products of a specific sector and how they generate and utilise the technologies of that sector.

[12] See, for example, Autio (1998); de la Mothe and Paquet (1998); Howells (1999); Acs (2000); Cooke et al. (2000, 2004); Asheim and Isaksen (2002); Doloreux (2002); Fornahl and Brenner (2003); Asheim and Gertler (2005); Doloreux and Parto (2005); Tödtling and Trippl (2005); Asheim and Coenen (2006); Doloreux and Revilla Diez (2007).

Foray 2003) tacit knowledge (Polanyi 1966) remains important for successfully carrying out innovation activities (Howells 2002; Gertler 2003). The exchange of tacit knowledge presupposes trust and personal contacts which are essentially facilitated by spatial proximity (Storper 1997; Morgan 2004). Forth, comparative studies on the governance of innovation have shown that sub-national territories differ strongly in their institutional setting and political decision making-abilities (Cooke et al. 2000).

The architecture of a RIS is of a complex nature. Based on the work of Autio (1998) we propose to grasp the structuring of a RIS by focussing on the following subsystems and crucial dimensions (see also Figure 1).

- *Knowledge generation and diffusion subsystem*: This subsystem comprises all those organisations that are creating and transferring technologies, knowledge and skills. Crucial actors are R&D organisations (universities, research institutes, public laboratories, etc.), educational bodies (universities, technical colleges, vocational training organisations, etc.), and technology mediating and other innovation supporting organisations (technology licensing offices, science parks, incubators, technology centers, etc.).

- *Knowledge application and exploitation subsystem*: Key agents in this subsystem are the industrial and service companies as well as their clients, suppliers, competitors and co-operation partners at the regional level. Such constellations are usually referred to as regional clusters.

- *Policy subsystem*: Government organisations and regional development agencies at the sub-national policy level constitute another RIS subsystem, providing finance and subsidies, and designing and implementing innovation and cluster policies (Cooke et al., 2000; Asheim et al., 2003; Tödtling and Trippl, 2005).

- *Local flows of knowledge and skills:* Ideally, there are different types of linkages within and between the RIS subsystems, leading to regional collective learning and systemic innovation. Keeble (2000) distinguishes between three key mechanisms of regional collective learning, including new firm spin-offs, labour mobility and networks. A more differentiated typology of linkages comprises market links, formal collaborations, informal networking (milieu) and spillovers (Tödtling et al., 2006). The precise nature of localised knowledge interactions, however, remains somehow disputed (Gertler and Levitte 2005; Gertler and Wolfe 2005; Malmberg and Maskell 2002, 2006; Porter 1998; Tödtling et al. 2006, Tödtling and Trippl 2007, Trippl and Tödtling 2007a).

- *Socio-institutional factors*: The common habits, routines, practices and rules prevailing in an area largely influence its innovation capacity, as they regulate the interactions between the innovation actors (Johnson, 1992; Gertler, 2004; Edquist,

> 2005). Consequently, institutional factors such as the dominating patterns of behaviour, the culture of co-operation or also attitudes towards innovation and technological progress are important RIS elements.

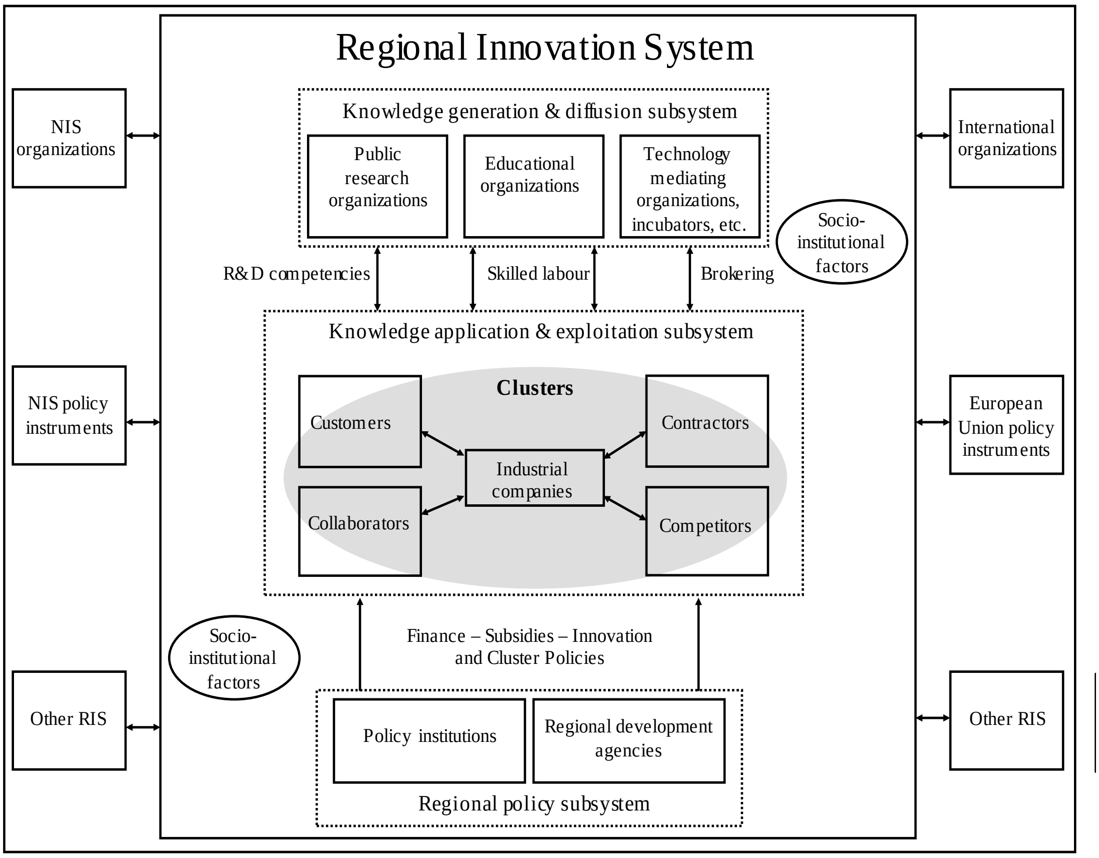
Regional innovation systems are embedded in *national* and *international innovation systems*, which taken together influence and shape the innovation activities of firms and their abilities to absorb and exploit new technologies such as ICT (see Figure 1). RIS are core entities in the globalising economy but other "layers" of innovation also matter crucially, giving rise to a complex, multi-level architecture of the set-up of knowledge production and application. The linkages between the character of RIS and the larger institutional frameworks, however, remain little understood (Asheim and Coenen 2006). More theoretical and empirical research is necessary to examine the *impact of national institutional framework conditions* as described by the varieties of capitalism approach (Soskice 1999), the theory on business systems (Whitley 1999) and the NIS literature (Lundvall 1992, 2007) on the form and functioning of RIS. Furthermore, there is the challenge to integrate more strongly the *international dimension* in studies of RIS and to analyse the *impact of ICT on the linkages between the regional, national and global innovation frameworks*.

RIS are inserted into a complex web of relations to national and international organisations and innovation systems. It is meaningful to draw a distinction between two relevant dimensions in this respect (Tödtling and Trippl 2005): The first dimension refers to the *inflow of international knowledge and expertise*, brought about by the extra-local contacts of regional firms and knowledge providers (Bunnel and Coe 2001; Oinas and Malecki 2002; Amin and Cohendet 2004; Maskell et al. 2004, 2006). The second dimension is related to *political governance* and its multi-level character. Policy interventions and actions undertaken at the national and European levels can constitute important *external impulses*, influencing the development and dynamics of a RIS (Cooke et al. 2000; Asheim et al. 2003)[13]. The

[13] With respect to the *distribution of competencies* between the regional, national, and European level enormous differences (with varying degrees of political autonomy for regions) within Europe have been detected (see Cooke et al. 2000). Nevertheless a pattern can be found indicating a complex division of labour (Cooke et al. 2000): At the *regional level* we can often identify competencies for the lower and medium levels of education, incubation and innovation centres, transfer agencies and, more recently, cluster policies (Boekholt and Thuriaux 1999). At the *national level* in many cases we find competencies for universities, specialised research organisations, and funding for R&D and innovation (OECD 1999). At the *European level* there are the structural funds, the RIS/RITTS programme, and the

last aspect dealt with above, i.e. the multi-level-governance dimension of innovation, deserves further attention. The past years have witnessed the rise of a large number of regional, national and European policy initiatives to promote both the production and use of ICT, calling for a sound coordination of different policy levels.

Figure 1: Structuring of Regional Innovation Systems



Source: Own modification of Autio (1998)

framework programmes for R&D and technological development (Landabaso and Mouton 2003; Oughton et al. 2002).

5.2 RIS and ICT

ICT and the Transformation of Knowledge Linkages

There is an increasing awareness of the powerful role of ICT as an *instrument of knowledge generation and transmission*. This is related to a pressure towards the codification of knowledge and the use of computerized knowledge management systems. In particular, the Internet and "search engine" such as Google have become a widely used source of relevant information also in science and research. Furthermore, ICT can potentially be regarded to essentially widen the spatial scope of innovation networks. An interesting compilation of potential effects of the Internet on the innovation process of firms (see Table 1) has been provided by Kaufmann et al. (2003).

Table 1: Potential effects of the Internet on the innovation process of firms

	Increase in the efficiency of the innovation process	Change in the innovation process or extension of the innovation network
Distribution of information	▪ Cheaper, faster and simultaneous distribution of information about innovation activities and within a co-operative innovation project ▪ Transmission of data which can be directly processed by the innovation partner	▪ Getting into contact with new types of innovation partners ▪ Getting into contact with more distantly located innovation partners (reaching new spatial levels)
Collection of information	▪ Faster, more frequent, continuous and cheaper collection of innovation-related information ▪ Direct processing of electronic data, easier integration in in-house knowledge management ▪ Integration of internal and external knowledge systems or databases	▪ New sources of information previously not aware of or not accessible due to distant location ▪ New sources of information previously not aware or not accessible due to 'relational distance' (different 'community of practice') ▪ Easier use of external databases and computational resources
Interactive communication	▪ Reduction of cost of communication in co-operative innovation projects involving distant partners ▪ More frequent and faster communication between distant partners	▪ Better integration of information flows improving the knowledge management of a firm

Source: Kaufmann et al. (2003)

There is work suggesting that the impact of the Internet on innovation varies from sector to sector. Anderson (2001), for example, found positive effects of the Internet on innovation only in the case of dynamic and complex industries (like electronics and instruments), but not in the case of mature and low-tech sectors (such as food, clothing and furniture). Kaufmann et al. (2003) in their study on Austrian firms, however, found no support for the view that specific sectors like high-tech or producer services are able to benefit more from using the Internet in their innovation process than other firms. Another key point, raised by Kaufmann et al. (2003) is that generally the Internet is more effective for improving the communication within existing innovation networks than for finding new knowledge sources and innovation partners. Moreover, they showed empirically that the effects of the Internet concerning the spatial extension of their innovation and knowledge linkages could be primarily found at the national and the European level, less at the global. Overall, there seems to be a weak globalizing effect of the Internet in most phases of the innovation process. *Spatial proximity* continues to matter, and both the local and the global level have their relevance as space for *knowledge interactions*. In the meantime this insight is well established in the literature. Many authors argue that both extensive relations within local clusters and RIS and strong connections to national and global knowledge sources are of importance (Bathelt et al. 2004; Gertler and Levitte 2005; Tödtling and Trippl 2007, Trippl and Tödtling 2007). This view clearly challenges the assumption of the dominance of one spatial level over another. On the contrary, Bathelt et al. (2004) have pointed out that “global pipelines” should be regarded as important complements to the “local buzz” produced in regional arenas.

RIS and the production of ICT

There are strong reasons to assume that regions and innovation systems differ regarding their ability to (1) “seed” ICT producing industries and to (2) adopt and use ICT for beneficial outcomes. Interestingly, much of the literature has been concerned with the former issue, i.e. the location and development of ICT clusters, whilst the issue of effective use of ICT has received less attention so far.

Much research has been carried out on the *geography of ICT production*, revealing a strong tendency of this sector towards a spatial concentration in clusters (Saxenian 1994; Swann et al. 1998; Keeble and Wilkinson 2000, Quah 2001; Koski et al. 2002;

Acconcia and Del Monte 2003). The propensity to geographical clustering is regarded to be a typical feature of knowledge based or high technology industries (Cooke 2002).

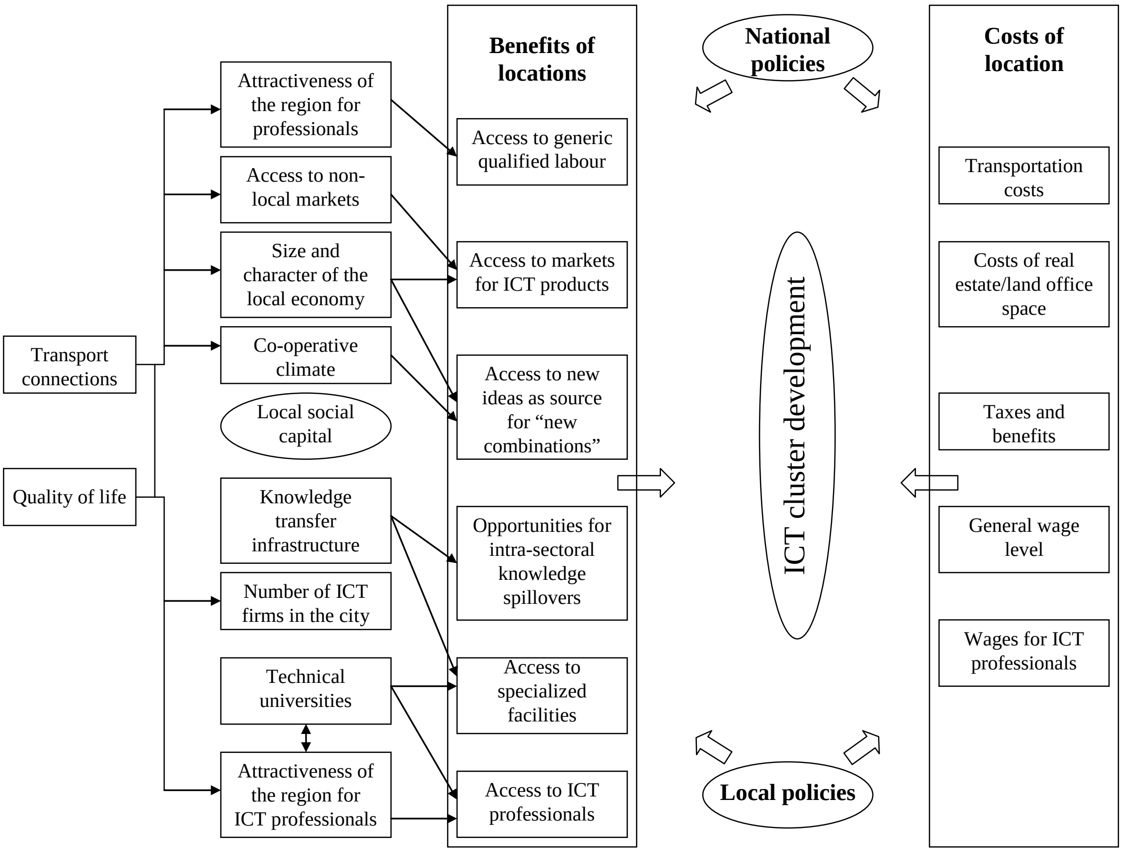
Some authors have argued that the rise of ICT clusters is strongly related to production and transaction cost advantages (see, for example, Scott 1988). Other scholars such as Saxenian (1994) and Cooke (2002), in contrast, pointed to the importance of advantages in terms of *knowledge exchange and spillovers*. According to van Winden et al. (2004) the development of ICT clusters depend upon access to the benefits of a certain location, the costs of that location as well as on the role of regional and national policies (see Figure 2).

The *spatial organisation of the ICT industry* has changed considerably in the past years. The traditional centres of ICT production, which are mainly found in highly developed countries and regions such as Silicon Valley, Route 128, and Texas in the U.S., Cambridge and the South-East region in the U.K., Munich and Cologne in Germany or Paris and Genoble in France are facing *increasing competition* from newly emerging ICT clusters in Taiwan (Hsinchu Science Park), India (Bangalore), Korea, Hongkong and China (Chen et al. 2006; Saxenian 2005). Research has shown that the *mobility of talent* and specialists has been a key factor for the development of these new dynamic ICT agglomerations in formerly peripheral regions. More precisely, the rise of new locations of ICT production in Asia has been considerably accelerated by highly-skilled engineers and venture capitalists, who retuned to their home countries after having studied and worked abroad (Saxenian 2002, 2005, 2006). By working or creating new companies in (and, thus transferring technological entrepreneurship and first-hand knowledge of financial institutions of the new economy to) their home countries, this talent played a key role as *"knowledge spillover agents"* (Trippl and Maier 2007) and impelled the emergence of a new global landscape of ICT production.

ICT clusters differ in terms of their origins, development paths and structuring (Matuschewski 2006). There exists a strong diversity of ICT clusters and their development is highly context dependent and context specific. Winden et al. (2004)

have provided an interesting typology, differentiating between *clusters specialised in R&D*, *local-demand-based ICT clusters* and *cost-based clusters*.

Figure 2: Determinants of ICT cluster development: a frame of analysis



In line with Cooke (2004) it can be argued that there are strong differences between RIS regarding their capacity to develop dynamic ICT clusters. Cooke (2004) has introduced a differentiation between traditional innovation systems (which he also calls *institutional regional innovation system* – IRIS) and new economy systems (which he refers to as *entrepreneurial regional innovation systems* – ERIS). Whilst an IRIS is well suited to promote the development of more traditional sectors with a synthetic knowledge base, high technology industries such as ICT which draw primarily from an analytical knowledge base best flourish in ERIS. The dynamism of ERIS rests – in sharp contrast to IRIS – on local venture capital, entrepreneurship, scientific excellence, market demand and incubators which support intense processes of knowledge exploitation.

Innovation processes in the ICT industry exhibit specific features, differing strongly from those in more traditional sectors as regards key knowledge sources, the role of codified and tacit knowledge and the types of knowledge links and local clustering (Asheim and Gertler 2005, Tödtling et al. 2006). Like other knowledge based sectors such as biotechnology, the ICT industry is regarded to be dominated by an analytical knowledge base. There is a strong reliance on scientific inputs and codified (or codifiable) knowledge is in general far more important than in traditional sectors which rely on a synthetic knowledge base (for an overview about the main features of analytical and synthetic knowledge bases see Table 2). An analytic knowledge base also implies that knowledge inputs are often derived from reviews of existing (codified) studies, knowledge generation is based on the application of widely shared and understood scientific principles and methods, knowledge processes are more formally organised (e.g. in R&D departments) and outcomes tend to be documented in reports, electronic files or patent descriptions. Although the codification of knowledge plays a decisive role in sectors with an analytical knowledge base, tacit knowledge is of relevance, too. In ICT and other knowledge based sectors there is much more systematic basic and applied research than in traditional industries. The rate of product and process innovations, notably of a radical nature, is high. R&D efforts are typically focused on generating radical innovations. Academic spin-offs and new firm formation are important mechanisms when it comes to the application and economic exploitation of new analytical knowledge. Research is done to a considerable extent within companies. Nevertheless innovating companies are highly dependent on external knowledge sources. Universities, government labs and other research institutions are crucial agents in this respect, providing scientific research inputs for innovating firms. Consequently, various forms of university-industry partnerships play a pivotal role in the process of knowledge generation and innovation.

Table 2: Synthetic and analytical knowledge bases

Key features	
Synthetic knowledge base traditional industries (e.g. industrial machinery, engineering)	**Analytical knowledge base** Knowledge-based industries (e.g. biotechnology, ICT)
• Dominance of tacit knowledge and practical skills	• Dominance of codified (codifiable) knowledge, complementary role of tacit knowledge
• Application or novel combination of existing knowledge	• Application of widely shared and understood scientific principles and methods
• Low levels of R&D	• Systematic basic and applied research, formally organised knowledge processes (e.g. in R&D departments)
• Strong orientation on solving specific problems articulated by customers	• Strong reliance on scientific research inputs from universities, government labs and other research institutions
• Learning by doing and interacting, user-producer relationships	• Learning by exploring, university-industry partnerships
• Incremental innovations	• Radical innovations

Source: Tödtling et al. (2006)

Recently, Trippl and Tödtling (2007b) have also argued that regions differ strongly in their capacity to promote the development of high technology sectors such as ICT. They propose a theoretical framework that links the rise of clusters to a dynamic analysis of regional innovation systems. Departing from the theoretical concept of regional innovation systems (RIS), a distinction between "RIS with strong potentials for high technology industries" and "RIS with weak potentials for high technology industries" is drawn. The key thesis suggested by Trippl and Tödtling (2007a) is that the development pattern of regional high tech complexes is strongly dependent on the strengths and the structuring of the respective RIS. *Regions that already host successful high technology industries constitute a favourable environment also for the rise of new knowledge intensive clusters,* even if the newly emerging sectors are different from those developed in the past. These areas are well endowed with generic factors such as excellent universities, knowledge mediating institutions, venture capital organisations and highly skilled mobile labour. Other key features of such regions often include a culture of academic entrepreneurship and high risk taking, a propensity to cooperate and share knowledge and positive attitudes towards innovation and technological progress. In such "RIS with strong potentials for high technology industries" the emergence and growth of a high technology cluster might be a spontaneous phenomenon, as it could build on existing generic functions and expertise necessary for “seeding” high technology sectors. Due to the tradition of these areas as high technology centres, a considerable body of knowledge is available at the local scale. Consequently, it can be suggested that knowledge residing within the region and its local circulation play a crucial role. The case of California is telling in this respect. Prevezer (2001, p. 18) analyses the emergence of the biotechnology sector in this region and shows that the industry “inherited a great deal from the earlier development of computing” in the area. Several of the prominent preconditions for successfully developing high technology companies were there, including excellent research organisations, experienced venture capitalists, a pool of highly skilled mobile labour, and good communication networks. Consequently, “the history of having grown the computing industry in California was relevant to the establishment of biotechnology in the Bay area” (Prevezer 2001, p. 25). Boston with its transitions from electronics, to computers and software, to biotechnology and where generic elements (research universities, venture capital, networks) have supported this transformation is another prime example for a “strong high technology RIS” (Tödtling, 1994).

In regions which have no tradition in promoting high technology industries and which have to be regarded as latecomer in a specific technological field, the rise of knowledge based sectors such as ICT is likely to take a different route. The argument is not in favour of building ICT clusters from scratch. Instead, the focus is on regions which possess important factors such as excellence in science or other competences rooted in the area on which a cluster can grow but lack the critical mass for spontaneous take-off. Enright (2003) refers to such constellations as “potential clusters”. Due to the regions’ weak commercialisation capabilities, they fail to capitalise on the existing assets. These areas often have little experience in commercialising scientific discoveries, a weak culture of risk taking, low levels of social capital, and frequently they lack crucial factors such as venture capital or a support structure specialised in promoting academic spin-offs. Tödtling and Trippl (2007a) refer to such settings as “RIS with weak potentials for high technology industries”. The key thesis proposed is that in such regions, the RIS must undergo a far reaching transformation for high technology clusters to emerge. Such RIS changes become manifest in the creation of a variety of new organisations, processes of institutional (un)learning and socio-cultural shifts. There are good reasons to assume that the state plays a stronger role in such regional settings to promote knowledge based clusters.

The rise and growth of knowledge based sectors in "RIS with weak potentials for high technology industries" is strongly linked to the capacity of the region to "rebuild" its RIS. The transformation of a regional innovation system is a complex and multifaceted process. The following two *key dimensions* deserve further discussion: Firstly, an adaptation and renewal of the institutional set up brought about by "implantation" of new elements is crucial in this context. More specifically, to promote excellent research and education institutes and to establish supporting agents such as science parks, academic spin-off centres, or technology licensing offices that are specialised in encouraging start-up companies are important preconditions for the development of the ICT industry. To strengthen the ensemble of specialised organisations, however, covers only one aspect of the reconstruction of a RIS. New routines, attitudes and patterns of behaviour must also emerge. To initiate changes in these "soft" institutions might be the most challenging endeavour in the process of creating a favourable environment for high technology industries. It is of special relevance in the knowledge generation and diffusion subsystem, reflecting the need that researchers learn to commercialise their scientific work by adopting more positive attitudes towards new firm formation and cooperation with industry. In the policy system also new routines seem to be of utmost importance. To encourage high technology industries, one cannot rely upon old policy recipes and traditional instruments such as subsidies, tax incentives or low cost labour (Audretsch, 2003; Feldman and Francis, 2004; Florida, 2005). It requires a substantial amount of policy learning, leading to a new mode of state engagement that is about investments in the knowledge infrastructure, and establishing conditions that attract talent and secure the availability of venture capital. Other measures to encourage entrepreneurship and to stimulate innovation interactions to promote a steady flow of knowledge at the regional scale may also deserve attention.

RIS and the use of ICT

ICT is regarded to be a generic technology, affecting *directly* and *indirectly* the entire economy and society. Looking at the level of firms, Bocquet et al. (2007) provide empirical evidence suggesting that the adoption of ICT is strongly related to firms' strategies, to their organizational practices and to their competitive environment.

As already noted by Freeman and Perez (1988) the diffusion of basic technologies such as ICT, is inextricably linked to and critically dependent on far-reaching *social and institutional changes*.

There are, indeed, strong reasons to assume that the provision of hard forms of infrastructure is far from being sufficient[14]. In the past decade it has become clear that a simple "transplantation" of ICT onto regional economies is not a viable strategy. The impact of ICT on growth is strongly dependent on the socio-economic conditions prevailing in the respective region. Key factors in this context include, for example, the production structure, i.e. the size of local companies and their embeddedness in larger supplier/customer networks. It is important to note that advanced networks cannot be formed by creating an ICT infrastructure if no networks existed before, pointing to the limits of a supply side approach. Beyond hard infrastructure also organisational quality and learning and innovation attitudes in companies, supporting organisations and in the policy system are vital, i.e. the existence of "soft infrastructure" elements.

It can be suggested that RIS differ enormously in their capacity to realize processes of institutional (un)learning and to transform themselves to become favourable environments for the adoption of ICT. Indeed, there is evidence that, while the potentials of ICT are in principle available to every area, the ways and the effectiveness with which regions exploit these potentials differ enormously across Europe (Cornford et al. 2006).

According to the i2010 High Level Expert Group (2006) there are several factors which have a strong bearing on the effective use of ICT. These include

[14] We are grateful to an anonymous referee for the following arguments on the importance of soft infrastructure elements.

- appropriate skills
- organisational change
- scope for experimentation
- appropriate management practices.

Cornford et al. (2006) assume that *regional innovation cultures* are a central key to unlock the potential of ICT in regions. More specifically, the authors point to the importance of various key factors, influencing the capabilities of regions to use ICT in an effective way. The most relevant factors or dimensions identified by Cornford et al. (2006) comprise:

- the proliferation of loosely articulated networks (open network structure) that enable the construction and propagation of meanings and values
- individual, institutional and collective learning
- the development of shared representations of possible futures, collective vision and reflexivity
- leadership
- a sound combination of regional openness and closure to the outside world.

Other RIS elements such as strong ICT research capacities, a well-functioning ensemble of educational organisations and knowledge transfer institutions specialised in ICT, a highly-developed local ICT producing industry, the establishment of local and global linkages for ICT diffusion as well as public authorities actively promoting the adoption of ICT might determine the “absorption capacity” of regions to exploit ICT in effective ways. The role of each of the factors listed above and their interplay, however, remain poorly understood and need both further theoretical efforts and empirical investigation.

The development of ICT also feeds back onto *the functioning of innovation systems* and RIS in particular. Many central innovations in ICT were triggered by the specific needs of components of innovation systems, by universities and researchers. So were the first Internet connections established between four US universities in order to allow them to cooperate more directly on defence projects. Later on the US National Science Foundation invested research money into a backbone network infrastructure and supported universities who wanted to link up to this network under the condition that "... the connection must be made available to ALL qualified users on campus." (Leiner et al., 2003) With this condition NSF for the first time opened up the network technology to a broader set of potential users.

At these times, the exchange of email messages, discussion in netnews and file transfer via FTP were the key applications. The respective software was closer to the needs of the machines than those of the users and therefore difficult to use. But even at these times, it was the needs and ideas of the research community which led to new proposals, new services and new, usually more user friendly, software.

A major breakthrough occurred in 1990, when Tim Berners-Lee circulated a proposal for an Internet based information management infrastructure which initiated the development of the World-Wide-Web (W3C, 2000). This Internet service became so popular within a short period of time that nowadays many people erroneously view the world wide web as the Internet. This development on the one hand triggered myriads of commercial services and on the other hand also provided the infrastructure for the development of the open source movement and triggered many contributions resulting from hours of voluntary work by "the community".

Today, the functioning of a RIS without the support from ICT in general and the Internet in particular is almost unimaginable. We can distinguish four major tasks in the functioning of a RIS that are strongly supported by ICT use:

1. information
2. communication and coordination
3. access to resources
4. cooperation and collaboration

As far as *information* is concerned, practically all members of a RIS in the developed countries provide extensive information on the Internet. This applies to universities and firms as well as to policy institutions and specific policy initiatives. It goes without saying that the use of ICT by the public policy system is not confined to the provision of information but it is far more multi-faceted as the discussion on the rise of different forms of e-Governance has shown[15]. The information is stored on servers and controlled by the respective institution. It typically serves various purposes. In addition to informing the general public such web-presences are used as instruments for marketing, public relations, image building, etc. Most of the time such information infrastructure is self contained and includes few or even no links to information

[15] We are grateful to an anonymous referee for this comment.

provided by other institutions. The opportunities for integrating information provided by others are utilized only to a limited extent. In this respect non-commercial, open source oriented information providers tend to be more open than others.

Communication and coordination are essential elements of a well functioning RIS. ICT provides many opportunities in this respect. They range from email messages and text messages sent to mobile phones to newsgroups, database-based membership systems and other forms of electronic communities. The electronic form of the communications allows the use of programs for routine tasks.

Access to resources mainly refers to knowledge resources. The information provided on the web grows continuously and constitutes a valuable resource for others. Of course, only codified knowledge can be provided in this way, which implicitly increases the relative importance of tacit knowledge.

While originally the quality of the information on the Internet was difficult to assess, in recent years more and more mechanisms of quality control have been developed and implemented. Most of them follow the principle of peer judgement and ask users to judge the quality of the respective piece of information. The published judgement then serves as a guideline for new users. These mechanisms point in the direction of more interactive forms of web use. Such technologies are often referred to as "web 2.0". A boost in quality also resulted from the increasing engagement of established media providers in electronic media. Most relevant scientific journals nowadays offer electronic access to their stock of peer-reviewed journal articles, in some cases clearly shifting emphasis away from the print version towards the electronic one.

Key players in electronic access to resources are the *indexing databases*. Services like Google have developed sophisticated indexing methods for all kinds of electronically available information and typically serve as entrance gates for Internet searches. From the point of view of a RIS, electronic access to resources serves as the link to the outside world that allows the integration of – codified and electronically available – knowledge from all over the world. To put it differently: The emergence of advanced ICT allows for the transfer of information and codified knowledge over long distances and, thus, enables regional actors to get access to ideas, knowledge and expertise that are not generated within the limited context of the regional innovation system. The circulation of tacit knowledge, which is acknowledged to be vital in the innovation process, is, however, still critically dependent on face-to-face contacts and spatial proximity.

The more recent developments in Internet services (Web 2.0) typically support electronic *cooperation and collaboration* among users. In Blogs, Wikis and similar services, the traditional differentiation between information provider and information user on the web becomes more and more blurred. The interactive services allow information users to become actively involved in the creation and servicing of information. They can evaluate, comment and often even alter the information provided by others. These services are currently developing very rapidly both in technical terms and in terms of standards and norms among users.

As this discussion shows, ICT provides many opportunities for improved functioning of a RIS. Most ICT based solutions are dramatically cheaper than corresponding non-electronic – mostly paper-based – versions. ICT makes it easier for a RIS to link up to the global pool of knowledge and expertise. The availability of information, however, does not necessarily mean that it can directly be used in the RIS context. A major task of the institutions of the RIS is therefore, to translate and adjust this information for the RIS context. Moreover, one should also not forget that only a specific type of knowledge – codified and electronically available – can be accessed in this way.

6 Globalisation and ICT in the Knowledge-Based Economy

ICT is a key factor driving economic globalisation and associated economic changes. Innovation in ICT is a critical component which can reduce both fixed and variable transactions costs of market entry and, more generally, economic performance. However, while the remarkable changes in the capacities of machines to process, communicate and store information have led to enormous efficiency and other gains, the potential downside of such rapid changes has been very rapid rates of physical and human capital depreciation. Accordingly, in such *rapidly changing environments*, there can be a high premium to having appropriately qualified human capital, which embodies the most recent technologies. In general, it is critical for the adaptability of a country or region that there be a continuous *upgrading of human capital formation, technological readiness, and technological infrastructure investments*. New technologies provide an opportunity for agents and regions to "leap frog" the shortcomings of their existing technologies and close performance gaps relative to that of technological leaders. However, existing technological positions may be reflecting underlying human capacity, financial and other constraints, which can not be reversed without sustaining investment policy initiatives over the medium and long-term. Accordingly, in the shorter term, technological change may be associated with significant hysteresis effects, whereby present levels of performance are essential for understanding a path dependency in rates of ICT diffusion. It should be noted that the size of firms may be a critical determinant of their access to resources, which are essential to investing and risk taking in order to promote ICT adoption.

Globalisation entails both increased international strategic interdependence and performance. It is a process through which a growing number of economic agents operate in an increasingly worldwide market place. As a consequence more and more agents find that their economic decisions have to take account of not just the *increased opportunities*, but also the *increased competition*, arising from an expanded range of relevant international locations that spans the planet. Thus, globalisation is inherently a double-edged sword. On the one hand, there are potentially increased opportunities, notably for heightened competitiveness and increased market sales over an expanded international geographic space. For example, relocation of different segments of a firm's activities can facilitate access to lower cost production sites and unique human capital and other resources, as well as lower cost intermediate goods and service suppliers. On the other hand, however, there is also increased pressure for local market restructuring in order to gain competitiveness. In that regard, labor markets often constitute an Achilles' heel of the economic adjustment processes triggered by globalisation.[16] Not only can labor, typically, be much less mobile than capital, or many types of goods and services, but also it is often difficult, or even impossible, to substantially upgrade human capital skills in the short to medium term. Thus, it should be emphasized that globalisation often entails both "winners" and, at least some, "losers". In the ICT context, this is clearly illustrated by the policy predicament of technologically disadvantaged countries and/or regions facing the "digital divide".

A consideration of some of the *principal determinants of globalisation* can offer valuable insights regarding its consequences and the design of optimal policy responses. Notably, to admittedly different degrees, many countries and regions have shown heightened willingness to embrace market liberalization, openness and facilitated market access. In general, *reduced transactions costs* hampering domestic and international trade in goods and services is an essential contributing factor to both the globalisation process and the relative competitiveness of specific countries and regions. In certain instances, such reduced costs have been accomplished through the dismantlement of various forms of government intervention and regulations which have previously hindered the free flow of goods and services. Pro-competitive policies have typically included the lowering of tariffs and discriminatory tax rates, the reduction or elimination of such non-tariff barriers as government standards, procurement policies and subsidies. Other factors which can reduce trade costs are pro-active government policies promoting market access, as through reduced transportation costs. Other dimensions of effective governance, such as excessive regulatory burdens and legal frameworks, can also be crucial for fostering a vibrant and internationally competitive business environment. Critically, in an increasingly linked and competitive international economic environment, there can be high costs to

[16] In many European countries the perceived social and governance constraints, associated with the functioning of labor markets appear to have generated more acute policy tradeoffs. The relative rigidity of certain EU labor markets can be contrasted with those in US and many Asian and/or developing countries.

policy inertia and the maintenance of segmented market conditions or other facets of the status quo, which are anti-competitive.

6.1 ICT-enabled Outsourcing, Offshoring, and Firm Performance

The ICT is a major driving force for outsourcing and offshoring. The rapid advancement of technology, in particular ICT, and the worldwide deregulation and competition in the telecommunications industry have led to a substantial decrease in adjustment and communication costs faced by firms. Firms no longer can be viewed as single entities that produce final goods. Increased *global connectivity* and the resulting *international cost saving opportunities* for production mean that firms now face decisions to *outsource and offshore*[17] components of their production process. Thus, Grossman and Rossi-Hansberg (2006) argue that there is a need for a new paradigm in international trade theory that places ‘task’ trade at the centre.

Many researchers have studied the implications of *increased openness and reduced costs of outsourcing* on the vertical integration decisions of firms. The literature on the "fragmentation" of the production process has provided interesting insights into the effects on trade flows, welfare changes and factor prices. Another strand of this literature examines the *formation of international hierarchical production teams*.

Lower communication costs are associated with higher levels of international offshoring. The model on the formation of hierarchical production teams proposed by Antras et al (2006) highlights the *important effect of communication technologies* on the *characteristics of international offshoring*. However, the quality of offshoring is lower. Furthermore, the model provides insight into how globalisation, viewed in terms of the formation of cross-country teams, affects the *organisation of work*, *size*

[17] Outsourcing is an arrangement in which an outside company provides activities for a company that could be or usually have been provided in-house. Offshoring is a subcategory of outsourcing. Offshoring refers to outsourced activities that are conducted abroad. Further classifications of outsourcing based on location and control/ ownership criteria include; captive onshore/ non-captive onshore outsourcing which refers to a shift from intra-firm supplies to an affiliated / non affiliated firm in the home economy. Captive / non captive offshoring refers to sourcing of activity from an affiliated / non affiliated firm abroad (World Trade Report, 2005). Metters et al (2007) discusses the current state of affairs in offshoring and the factors that have created the present environment. They argue that US government neglect, foreign government activism, technological change, cultural change in relation to services processes among business people and cultural relationships among countries combined to create the current environment of services offshoring.

distribution of the firms, the structure of earnings of individual. They show how these outcomes impact on production, consumption and international trade in the global economy. The less skilled agents specialize in production and more skilled agents specialize in problem solving. Globalisation leads to better matches for all southern workers but only for the best northern workers. As a result, globalisation increases wage inequality among non-managers in the South, but not necessarily in the North.

It has been argued that European countries slow take up of ICT is acting as a barrier to fragmentation and specialisation of business processes. Abramovsky and Griffith (2005) examine the role of ICT investment in influencing a firm's decision to outsource and offshore services and find that ICT intensive firms purchase greater amounts of business services on the market. They also find that these firms are more likely to purchase business services offshore. Specifically they find that both ICT investment and Internet use increases the probability of a firm offshoring by 12 per cent.

Bhalla et al (2007) investigate *the link between a company's performance and the extent of its offshoring of IT-enabled services*. However, they fail to find such a link and argue that further research is warranted into what are the expected benefits from offshoring and when is the optimal time for a firm to offshore. Gorg and Hanley (2004) examine the relationship between *outsourcing and profitability at the level of the plant*. They find that on average, other things equal, larger plants in the manufacturing sector benefit from outsourcing materials inputs while small plants do not. Results for the service sector are not clearcut.

A large proportion of service sector occupations are found to be potentially offshorable. Van Welsum and Vickery (2005), apply the following classification of occupations based on four "*offshorability attributes*" (i) intensive use of ICT (iii) an output that can be traded and transmitted in a way that is enabled by ICT (iii) level of codifiable knowledge and (iv) no face-to-face requirements. Based on data for several OECD countries they calculate that 20% of total employment carried out functions that could potentially be offshored as a result of rapid technological advances and increase tradability of services.

There is a large variation in the estimates, provided by other studies which have conducted similar analyseis, of *total employment potentially offshorable*[18] Bardhan and Kroll (2005) classify employment based on job characteristics and estimate that 11 percent total employment in the US in 2001 was offshorable compared to a figure of 44% estimated by Forrester Research and reported in Kirkegaard (2004). The large variation is mainly due to differences in occupation classification criteria. Jensen and Kletzer (2005) identify potentially tradable service sector occupations based on spatial clusters and estimate that 30% of employment in the US may be affected by offshoring. They fail to find conclusive evidence of weaker employment growth in tradable occupations than in non-tradable activities.

From a policy perspective, it is interesting to uncover the *underlying factors of the proportion of offshorable occupations in total employment.* Van Welsum and Reif (2006) use data from 12 OECD countries (including 9 EU countries) over the period 1996-2003 and estimate the factors driving the shares of potentially offshorable clerical and non-clerical occupations in total employment. They distinguish between FDI in manufacturing and services.[19] The grouping of occupations is very relevant as the clerical group include jobs that can be substituted for by ICT therefore a differential pace of adoption and integration of technology can have a different effect across countries. The results suggest that the share of exports of business service in GDP, the share of ICT investment in total gross fixed investment, share of services sector in GDP and human capital are positively associated with an increase in the share of employment in potentially offshorable non-clerical occupations, while the share of imports has an offsetting effect on the share of employment in potentially offshorable non-clerical occupations. They find that an increasing share of employment in potentially offshorable clerical occupations, the exports to GDP ratio, the human capital measure, share of hi-tech output in GDP, and product market regulations are positively related. Imports of business services, declining trade union densities and rising share of services in GDP are negatively related.

Bunyaratavej et al. (2007) investigate *the determinants of the location of services offshoring*. They relate services offshoring to the literature on international business

[18] Summarised in van Welsum and Vickery, 2006, Mankiw and Swagel, 2005.
[19] This paper is an extension of their previous analysis van Welsum and Reif (2006)

research of the cost of doing business abroad (CODBA), liability of foreignness (LOF) and institutional theory. They find that important location factors for services outsourcing are lower labour costs and human capital while due to telecommunications technology proximity to major markets is less vital. Institutional theory emphasises the critical role *institutions* play in an economy lowering *transaction costs and information costs* and facilitating interactions. Locating in countries with similar culture, political systems, economic systems, legal systems to the home country should reduce CODBA/LOF and make easier the firms' integration with the local institutional environment. Bunyaratavej et al. (2007) find that firms are more likely to offshore to locations where wages, culture, education and infrastructure closely resemble their home country.

6.2 The Impact of Globalisation and ICT on Regional Economic Performance

Globalisation both reflects and impacts a number of dimensions of firms' and other entities' domestic and international economic performance. From the perspective of regional economic performance, globalisation potentially not only offers unique opportunities for regions to reap returns from unique assets on expanded, increasingly worldwide markets, but also permits them escaping the constraints of unfavorable local economic conditions. *Reduced international transaction costs*, facilitated by the use of ICT, constitute a critical component of globalisation. Such cost savings can redefine the nature and functioning of markets, their interconnectivity, as well as the relative importance of spatial economic factors. As a result, there are potentially asymmetric changes in certain of the relative costs of agents, which are often interrelated in complex ways with spatially sensitive economic factors and, in turn, agents' competitiveness. For example, while a firm in a remote region, may be able to effectively use e-marketing to sell an unique product, its ability to satisfy customers could be dependent on complementary infrastructure investments which would reduce the transportation costs for the delivery of the goods to potential clients.

The progressive build-up of *trade and FDI* are interrelated with other specific processes such as *outsourcing, fragmentation, offshoring or delocalization of economic activities*. As previously discussed, one both positive and negative aspect of globalisation is increased pressures for international competitiveness. As Michael

Porter and other have emphasized, this leads firms to decentralize their value-added chains on a global level in order to avail themselves of sources of reduced costs and/or unique resources. Broadly speaking, ICT can be viewed as countering traditional spatial constraints, which required the bundling of complementary activities in specific locations. ICT facilitates the locational dispersion, fragmentation and decentralization by reducing organizational costs of coordination. This applies to the exchange of goods and services both within and outside institutions' original structures.

In the case of *outsourcing*, for example, ICT can permit the substitution of potentially lower cost external suppliers which can have cost advantages relative to internal supply by an institution envisaging such outsourcing. Traditional reasons for such external cost advantages include access to unique technologies, resources, including skilled and unskilled labor, as well as suppliers' ability to achieve economies of scale and/or scope by serving multiple clients. Specifically, outsourcing is often driven, to a significant extent, by low efficiency wages, as illustrated by the case of software consulting services provided in Ireland and India. These in turn depend on the supply of well-qualified workers, who can be both locally and foreign trained and/or recruited.

ICT can be viewed as vital to the effective communication, processing, and use of information permitting the *efficient coordination* of the timing of external supply, relative to an institution's internal demands. Moreover, there are often quality control issues, which can require the sharing of potentially complex information regarding the nature of production processes. An essential insight here is that *globalisation entails a real challenge to the measurement of ICT's contribution to an institution's competitiveness*. Specifically, an assessment of the overall contribution of ICT investment to enhanced productivity and profitability may be obfuscated by the fact that ICT is interrelated with many different dimensions of the institution's activities and structure.

6.3 Policy Stakes of Globalisation, ICT and Regional Development

The *heightened economic interdependence* entailed by economic globalisation provides a strong rationale for *proactive government policies*, notably *to promote technological innovation and to foster knowledge-based economic activities.* Greater policy cooperation and coordination, both between countries and regions within and between countries, is required for a variety of reasons. These include a shift in the relative heightened strength of markets, as compared to individual governments and international institutions. In large part, this is due to increasingly high degrees of capital mobility and greater competition between countries and regions on an international scale, in order to attract the many faceted activities of multinational corporations.

Economic globalisation is also associated with more *market failures,* with associated greater scope for *negative international externalities*, as well as *inter and intra-regional, externalities*. Such externalities can be either positive, or negative, as in the cases, respectively, of R&D spillovers or job losses. There is also an increased *vulnerability to foreign market and government failures*, as illustrated by the case of pirated computer software in many countries worldwide.

Globalisation also entails *heightened opportunity costs of poor policy choices and design*. In part, this is, as previously discussed, due to the increased pace of technological change. The heightened interdependence linked to economic globalisation is redefining the gap between technological frontier countries/regions and economic leaders, on the one hand, and technological followers and poorer countries/regions. Over time there can be major distributive effects, potentially leading to sharp policy tradeoffs between policies favoring competitiveness and social redistribution. In addition, policy stakes are often accentuated by marked asymmetries in economic agents' initial economic positions. Thus, the *policy options* available to agents may be quite dependent on their initial wealth, as illustrated by the case of relatively poor and rich regions within and across countries. Such asymmetric positions can mean that the "core" of coordinated policy solutions at international levels may be relatively limited, but these may be easier to resolve at regional levels given heightened perceptions of shared communities of interest. Thus, proactive interregional and intraregional policies may be first-best policy responses. Longer-term economics stakes can be defined by potentially virtuous or vicious economic growth paths.

Thus, it appears that *proactive country and regional policies favouring innovation and ICT diffusion* are increasingly of primordial importance. The development of appropriately skilled human capital can be crucial for success, as illustrated in Ireland and Singapore or by the cases of Silicon Valley, Seattle, as well as by Cambridge UK or USA. Effective policies need to support mechanisms that generate a concentration of certain economic activities in order to realize increased scale economies and/or agglomeration effects, which correspond to the internalization of positive location-specific spillover effects (i.e. externalities).

In an increasingly knowledge-based economy, worldwide, the latter include R&D spillovers, which can be linked to a variety of factors including the *quality of national and regional innovation systems*. More specifically, *technological competitiveness* can be critically impacted by university-industry linkages, the state of human capital development, labor-market synergies linked to complementary training in different companies, etc. In general, many regions tend to have more specific centers of specialized activities, so that the former strategies may be preferable. Nonetheless, the financial and other constraints, arising from smaller sizes and resources, also suggests the need for regions to foster intra and inter-regional networks, in order to achieve scale economies and to foster positive knowledge and other spillover effects.

7 Summary and Conclusions

7.1 Summary

The Economic Impact of ICT Diffusion

The rapid development, adoption, and use of ICT innovations have transformed economies at the national and the regional level and all their sectors. In this respect, ICT functions as a *new general purpose technology*, which impacts economies both broadly and deeply by generating a wide array of new products, production processes and services. Furthermore, ICT has given rise to new industries within both the manufacturing and the service sector. However, it is a common feature of new general purpose-technologies that it takes a long time before they are implemented (including the necessary organisational changes) and used in such a way that they could develop their abilities to the fullest.

The adoption of ICT allows the reduction of transaction costs and leads possibly to more efficient markets. The emergence of new goods and services as well as changes in the characteristics of old goods and services due to the use of ICT, including the ways goods and services are produced and distributed lead to changes in market structures and competitive conditions affecting and creating new opportunities for small firms and entrepreneurs. As ICT are routinely deployed in organisations to re-engineer processes, gain new strategic advantages, or network across organisational boundaries, they change both the internal organisation of companies and other organisations and the relationships between companies and organisations.

In addition, *the spread of ICT is changing the labour market by generating new ICT-occupations* and at the same time changing the requirements for non-ICT jobs. Due to the *structural changes generated by ICT*, employment is increasing in some sectors and declining in others.

There are *three main channels* through which ICT affects economic growth. The first channel is the *emergence of new sectors* embodying *new technologies* including the ICT-producing sectors themselves. In this case growth comes from two sources: (i) new sectors exhibit higher growth rates of value added, productivity and incomes and will thus function as a source of growth for the whole economy, and (ii) new sectors change the conditions of other sectors of the economy by changing relative prices, and by providing a new set of inputs that raises productivity either by the introduction of new or improved products or new production methods. The production of ICT and the emergence of new ICT-based industries contribute directly to increase GDP and to boost aggregate productivity.

The second channel is *increased investments in ICT* by companies and governments which lead to labour and total factor productivity growth. Investments in ICT complement or replace investments in other capital goods and increase the capacity of the production of ICT-using sectors and industries.

The third channel has an indirect growth impact, namely *spillover effects*. Spillover effects of technological advances from industries producing ICT to industries using ICT result in an increase in total factor productivity.

The benefits of investing in and using ICT depend on sector-specific effects. ICT are more important to raising productivity in certain sectors than in others and since different countries have different sectoral specialisation, their gains from investing in and using ICT will differ. Investments in and use of communication network technologies present a special case because of the benefits derived from spillover and network effects. Furthermore, since the conditions to develop and to use ICT varies substantially between regions, we expect *large variations between regions* in the timing as well as in the extent that they are affected by ICT.

Regional Dynamics and Transformations During the Deployment Phase of ICT

Locational choice is increasingly becoming governed by access to particular skills, technology, and knowledge, as well as entrepreneurial talent and venture capital. Of particular importance is the provision of ICT skills, ICT technology, ICT knowledge, ICT services, ICT entrepreneurial talent, and ICT competent venture capital. This follows from the fact that in most advanced economies an ever increasing share of economic inputs and outputs is in the form of ICT and knowledge.

The increased use of ICT enables major reductions in geographical transaction costs by reducing spatial information frictions. Examining the interrelationships between three variables – increasing returns due to scale economies, demand for final products and geographical transaction costs – in a world with monopolistic competition makes it possible to draw some general analytical conclusions concerning the effects ICT-induced reductions of geographical transaction costs. When geographical transaction costs are reduced, producers in large regions, i.e. regions with large home markets, which already have good opportunities to exploit economies of scale due to a large home market, can lower the production costs by also delivering to other regions, i.e. by increasing their exports. When exports increase, there will also be increases in incomes, which induce more producers of differentiated products to start production in the large region. Increased exports also imply an increased demand for differentiated inputs, which will induce more producers with their internal scale economies to start producing such inputs. As a consequence, we have a situation with cumulative causation or positive feed-backs initiated by the effects of ICT on geographical transaction costs. It follows that investments in ICT and particular in communications equipment stimulate further agglomeration.

The literature on innovation systems strongly indicates that *knowledge flows, including spillovers are at the core of regional development.* Since knowledge sources have been found to be geographically concentrated, location is crucial in understanding knowledge flows. In addition, the capacity to absorb flows of new knowledge is facilitated by geographical proximity.

Large, dense regions offer special advantages in terms of knowledge flows and knowledge spillovers, since they combine the localisation of clusters in specific industries with industrial diversity, i.e. with a range of different industrial clusters. When a (large) functional region has achieved an initial advantage in knowledge production due to e.g. a large pool of well-educated labour and a rich supply of ICT capital assets, it will attract (i) knowledge-creating and knowledge-utilising firms, since it offers opportunities to take advantage of increasing returns in knowledge production and knowledge use including imitation, and (ii) knowledge-rich labour, which wants to take advantage of the increasing demand for its skills. With increased knowledge intensity in larger regions we can expect increased investments in ICT capital assets, which will further reduce geographical transaction costs.

Regional Innovation Systems and the Layers of Innovation

ICT and regional systems of innovation are closely connected and mutually influencing one another. Regional absorption and application of ICT is an important factor for the functioning of the respective regional innovation system (RIS). At the same time, the structure of the RIS is a major location factor for ICT industries of various types and may also stimulate the regional adoption and exploitation of specialized forms of ICT applications.

The innovation system approach views innovation as an evolutionary, non-linear and interactive endeavour that requires intensive interaction between actors. These interactions can substantially be supported by the application of various forms of ICT. The innovation system approach also highlights the importance of formal and informal institutions for the innovation process. In recent years regional scientists have emphasized that many of these interactions are spatially bounded thus leading to a strong regional component in innovation systems. Consequently, they argue in favour of regional innovation systems (RIS). Two key arguments in this respect are the spatial limitations for knowledge spillovers and the importance of tacit knowledge for many innovations.

RIS is a complex system of various interrelated subsystems: the knowledge generation and diffusion subsystem, the knowledge application and exploitation subsystem, the policy subsystem, the local flows of knowledge and skills, and the socio-economic factors. In addition to this complex structure, regional innovation systems are also embedded in national and international innovation systems and thus linked to global trends of economic development. These linkages influence and shape the innovation activities of firms and their abilities to absorb and exploit new technologies such as ICT. The chapter underlines the complex, multi-level architecture of knowledge-production and application and their dependence on national and international institutional framework conditions. Potentially, ICT plays a crucial role in linking these layers of the innovation system.

The relationship between ICT and RIS elements is analyzed from three angles: first, ICT and the transformation of knowledge linkages, second, RIS and the production of ICT, and third, RIS and the use of ICT.

As far as the first aspect is concerned, *ICT is viewed as an important instrument of knowledge generation and transmission*. The intrinsic advantages of ICT in storing, transforming, and transmitting information exerts pressures towards the codification of knowledge and the use of computerized knowledge management systems. Science and research widely use the Internet and electronic search engines as sources of information. In this way the availability of those instruments that were to a large extent developed by science and research widens the spatial scope of innovation networks. Empirical evidence, however, shows that ICT is more effective for improving the communication within existing innovation networks than for finding new knowledge sources and innovation partners. Nevertheless, ICT helps to establish the "global pipelines" that are important complements to the "local buzz" produces in regional arenas.

The geography of ICT production, the second angle used in the chapter, has received much attention in research, revealing a strong tendency of the sector toward *spatial concentration in ICT production clusters*. The historical spatial organization of the ICT industry has changed considerably in recent years. New ICT clusters have emerged in Asian countries, in some cases stimulated by the mobility of specialists who returned to their home countries. Such spillover agents seem to play an important role in the creation of new ICT based clusters.

The empirical evidence about ICT production clusters reveals differences in the economic base of such clusters. Some are motivated by local R&D, some by local demand, and some by low cost in the area. Also, regional innovation systems differ in their ability to generate ICT clusters. While traditional regional innovation systems seem to be better suited to promote more traditional sectors because of their reliance on a synthetic knowledge base, R&D driven ICT production clusters require an analytical knowledge base that is argued to florish best in a so called "entrepreneurial innovation system" which emphasizes local venture capital, entrepreneurship, scientific knowledge, market demand, and incubator institutions. The ICT industry is regarded to be dominated by an analytical knowledge base, relying on scientific inputs and codified knowledge. R&D efforts in a RIS targeted toward ICT production typically focus on generating radical innovations. Academic spin-offs and new firm formation are important mechanisms in this respect. Universities, government labs and other research institutions provide scientific research inputs for innovating firms. Regions well endowed with generic factors such as excellent research universities, knowledge mediating institutions, venture capital organizations and highly skilled labour enjoy a better chance to generate successful ICT clusters. Since regions already hosting successful high technology industries typically fall into this category, one can expect a significant path dependence in these processes.

In regions characterized by more traditional regional innovation systems the RIS will have to undergo a far reaching transformation for high technology clusters to emerge. Rebuilding a RIS is a complex and demanding process. The promotion of excellent research and education institutes and of supporting agents like science parks, academic spin-off centers, etc. is just one aspect of the necessary restructuring. New routines, attitudes and patterns of behaviour must emerge, requiring substantial amounts of learning and unlearning the old routines and attitudes. This is particularly challenging for policy.

As far as the third perspective, RIS and the use of ICT, is concerned, it is argued that *the adoption of ICT is strongly related to firms' strategies, to their organizational practices and to their competitive environment*. A simple "transplantation" of ICT onto regional economies does not seem a viable strategy. Success depends upon the socio-economic conditions and in addition to hard infrastructure also on the existence of soft infrastructure elements like organizational qualities and innovation attitudes in companies. While the potentials of ICT are in principle available to every region in Europe, evidence shows that the regions differ enormously in the effectiveness with which they exploit these potentials. This "absorption capacity" to exploit ICT effectively is closely related to the availability of the mentioned elements of an entrepreneurial regional innovation system.

It is argued that *ICT also feeds back onto the functioning of the respective RIS*. In recent history it was often the needs of major components of the innovation systems that triggered successful innovations in ICT. We discuss the development of the Internet as a typical example of this relationship and the way in which this important element of ICT can support key tasks in the functioning of a RIS: information; communication and coordination; access to resources; and cooperation and collaboration.

Globalisation and ICT in the Knowledge-Based Economy

ICT is a key factor driving economic globalisation and associated economic changes. Innovation in ICT is a critical component which can reduce both fixed and variable transactions costs of market entry and, more generally, economic performance. However, while the remarkable changes in the capacities of machines to process, communicate and store information have led to enormous efficiency and other gains, the potential downside of such rapid changes has been very rapid rates of physical and human capital depreciation. The size of firms may be a critical determinant of their access to resources, which are essential to investing and risk taking in order to promote ICT adoption.

The ICT is a major driving force for outsourcing and offshoring. The rapid advancement of technology, in particular ICT, and the worldwide deregulation and competition in the telecommunications industry have led to a substantial decrease in adjustment and communication costs faced by firms. Increased *global connectivity* and the resulting *international cost saving opportunities* for production mean that firms now face decisions to *outsource and offshore* components of their production process.

ICT intensive firms purchase greater amounts of business services on the market. It has been argued that European countries slow take up of ICT is acting as a barrier to fragmentation and specialisation of business processes.

A large proportion of service sector occupations are found to be potentially offshorable. Recent research suggests that the share of exports of business service in GDP, the share of ICT investment in total gross fixed investment, the share of services sector in GDP and human capital are positively associated with an increase in the share of employment in potentially offshorable non-clerical occupations, while the share of imports has an offsetting effect on the share of employment in potentially offshorable non-clerical occupations. Furthermore, an increasing share of employment in potentially offshorable clerical occupations, the exports to GDP ratio, the human capital measure, share of hi-tech output in GDP, and product market regulations are positively related. Imports of business services, declining trade union densities and rising share of services in GDP are negatively related.

From the perspective of *regional economic performance*, globalisation potentially not only offers unique opportunities for regions to reap returns from unique assets on expanded, increasingly worldwide markets, but also permits them escaping the constraints of unfavorable local economic conditions. Reduced international transaction costs, facilitated by the use of ICT can redefine the nature and functioning of markets, their interconnectivity, as well as the relative importance of spatial economic factors. As a result, there are potentially asymmetric changes in certain of the relative costs of agents, which are often interrelated in complex ways with spatially sensitive economic factors and, in turn, agents' competitiveness. For example, while a firm in a remote region, may be able to effectively use e-marketing to sell an unique product, its ability to satisfy customers could be dependent on complementary infrastructure investments which would reduce the transportation costs for the delivery of the goods to potential clients.

By reducing organizational costs of coordination, ICT facilitates the locational dispersion, fragmentation and decentralization. This applies to the exchange of goods and services both within and outside institutions original structures.

Due to the increased pace of technological change, globalisation also entails heightened opportunity costs of poor policy choices and design. The heightened interdependence linked to economic globalisation is redefining the gap between technological frontier countries/regions and economic leaders, on the one hand, and technological followers and poorer countries/regions.

Thus, it appears that *proactive country and regional policies favouring innovation and ICT diffusion* are increasingly of primordial importance. Effective policies need to support mechanisms that generate a concentration of certain economic activities in order to realize increased scale economies and/or agglomeration effects, which correspond to the internalization of positive location-specific spillover effects (i.e. externalities). In an increasingly knowledge-based economy, worldwide, the latter include R&D spillovers, which can be linked to a variety of factors including the *quality of national and regional innovation systems*. More specifically, *technological competitiveness* can be critically impacted by university-industry linkages, the state of human capital development, labour-market synergies linked to complementary training in different companies, etc.

7.2 ICT, Innovation Systems and Regional Development: An Integrated View

In the previous chapters of this paper we have discussed various aspects of the complex relationship between ICT and regional development. We have highlighted the key aspects of ICT as a general purpose technology, discussed the economic impacts of ICT diffusion from a macro as well as from a micro perspective, and discussed the spatial consequences of ICT diffusion. The fairly general concepts of regional innovation systems and of globalization were analysed in order to propose a organizing framework for the mechanisms under discussion.

In this section we attempt to combine these elements into an integrated argument. Given the complexity of the issue that has become apparent in the previous chapters, this integration cannot be made in the form of a consistent and rigorously formulated model, but only in terms of tying together the main arguments.

Although they were made from different conceptual and theoretical perspectives, many of the arguments brought forward in the previous chapters were quite similar and closely related. For example, *the role of knowledge and human capital* was not only stressed in the discussion of regional innovation systems in chapter 5, but also in chapters 3 and 4. Similarly, *the interdependence of regional economies and the competition between them*, which is a major argument *in the context of globalization*, is also stressed in chapter 5 where we discussed *the interdependence between regional, national, and international innovation systems.*

The relationship between ICT and regional development is manifold and complex. In our view the concepts of globalization and (regional) innovation systems are suitable frameworks for the discussion of this relationship. Neither “ICT” nor the “Region” should be viewed as homogeneous entries. Both consist of numerous elements and are in close competition with other regions or other sectors of the economy. This competition ties both regions and ICT sector firms into the processes of globalization: increased capital mobility, rapidly changing environments, increased competition with declining profit margins, etc.

The tendency of ICT to reduce transaction costs and to facilitate communication and control over longer distances is a major factor behind globalization. It opens up new markets and new opportunities for firms, in many cases radically changing quite traditional industries. The respective competitive pressures force companies to reconsider their internal organization as well as their position in the value added chain, which generally becomes more fragmented. The application of ICT allows for new forms of (spatial) specialization leading via outsourcing and offshoring to a new structure of the spatial division of labour. The corresponding processes of capital mobility directly impact regions, their population, economy, and public policy.

All these processes take place in a dynamic rather than in a static economic environment. *The above mentioned competitive pressures force companies into a continuous race for the innovative advantage; be it in terms of new products, new production processes, or new forms of organization*. As has been discussed above, however, the innovation process is highly complex, influenced by many factors, many of which themselves are influenced by innovation, and highly uncertain and risky in its outcome. The literature on innovation systems argues that the innovation process is of complex dynamics, path dependent and subject to cumulative feedback loops. The availability of specific types of ICT, for example, is an important prerequisite for innovations in ICT. Such mechanisms can lead to self-sustained growth processes on the one hand, or to lock-in in a technological dead-end on the other.

A key factor in the (regional) innovation systems literature is knowledge. As has been described in chapter 5 above, knowledge can be of very different types. It can be quite general in the form of basic human capital or highly specific and applicable only to a very special task. It can be codified and therefore easily transferable or tacit and thus tied to the individual possessing this knowledge. Different types of knowledge, be it part of a synthetical knowledge base or an analytical knowledge base, are needed for solving different types of problems. Accumulated knowledge from the past may be both, a prerequisite for or a factor hampering the acquisition of new knowledge.

Since regional development in the long run depends upon successful innovations, generation of knowledge and the design of the region's innovation system are key factors for the economic viability of a region. Inventions and new information are necessary, but by no means sufficient for successful innovations. The regional economy and population also need the capacity to absorb the new elements and to utilize them to their full capacity. In this sense, the availability of ICT in a region is no guarantee for its productive use in the regional economy. The region also needs the human capital and the RIS environment in order to absorb the technology and to realize its potential benefits. Many factors like the quality of educational institutions, the availability of venture capital, a positive attitude toward risk taking and innovation, etc. are claimed to be necessary environmental factors.

A major element of the innovation process is the ability and skill to combine information and knowledge from various sources with previous experience. *The ability of ICT to reduce transaction costs, ease the exchange of information, and to store and organize codified knowledge makes it an important resource for the generation of new skills and the innovation process in general*; in addition to the more traditional factor that the introduction of ICT can improve many products, services, and production processes. In addition to the externalities generated by the spillovers of knowledge from innovative agents to others, the network externalities of the ICT infrastructure contribute to the complexity of the relationship between ICT and regional development.

This complex and highly nonlinear set of relationships between the various aspects of ICT, the many elements of the innovation system and the innovative capacity of a regional economy facing the competitive pressures of globalization, represents a major challenge for policy at the regional, national and European level. In such a complex system there does not exist the one critical policy variable. It typically requires the contributions of most of the factors discusses so far. Because of complementarities lack of one factor may severely hamper or even block the whole system. Because of the inherent path dependence minor differences between regions may set them off at quite different trajectories in terms of ICT adoption, innovative environment, and regional economic prosperity. The interplay of those factors is essential, but hardly observable in aggregate statistics. It needs a case study approach to identify the most critical factors and to observe their complex interrelation.

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