ICT clusters in development: Theory and evidence

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ABSTRACT

This paper analyzes the impact of information and communications technologies (ICT) on economic growth and agglomeration, emphasizing outcomes for regional inequality. ICT significantly displays the same features—increasing returns, knowledge spillovers—that drive both growth and agglomeration. However, in the data, cross-economy inequality has been rising for longer than has ICT been perceptibly influencing economic performance. In Europe, nation states show no special advantage in using ICT as a driver for economic growth; ICT clusters seamlessly transcend national borders.

Keywords: centrifugal, centripetal, concentration, growth, increasing returns, information and communications technology, knowledge, spillover, technology, weightless economy

JEL Classification: D30, O10, O18, O57

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1 Introduction

Many observers suspect economic growth to be inextricably associated with inequality: growth alone need not bring about unalloyed, uncontroversial increases in economic well-being because rising average income levels might come together with increasing disparities between rich and poor.

Prominent theories on the sources of economic growth reinforce these concerns. Theories that especially do so are those that relate growth to increasing returns—where the more production occurs, the greater is productive efficiency—and to technological progress—where advances in science and knowledge are what drive economic growth (e.g., Aghion and Howitt, 1998; Grossman and Helpman, 1991; Romer, 1986, 1990). Versions of these theories imply a *path dependence*, where success breeds further success—those already rich or technologically advanced become more so; while those poor, similarly, become progressively poorer (Durlauf, 1993). Put another way, economic growth inevitably brings greater inequality.

While increasing returns and technological progress are conceptually distinct, both theory and evidence suggest they often come together and result in technological lock-in (David, 1985) so that technologies that initially have an advantage—real or imagined, substantive or accidental—tend to endure.

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The same circle of ideas arises prominently in two other distinct areas: First, economic geography and second, information and communications technology (ICT). Arthur (1994) and Krugman (1991a,b) have emphasized that the concept of increasing returns allows insightful analysis of the location in space of economic activity. Spatial agglomeration—geographical clusters—then can result from the same forces as technological lock-in. Geographical concentration is just another form of inequality, only in a spatial dimension, rather than across people or across countries. The higher the clustering in only a small number of areas, the greater the income inequality.

Economic analysis of ICT takes the ideas one step further. ICT is, on the one hand, the most recent, most exciting manifestation of general technological progress—hence contributing directly to economic growth—and, on the other hand, generally seen to be an industry where increasing returns is pervasive: Creating the first copy of a new working piece of software or the first design of a new semiconductor chip is costly, but running off further copies costs virtually nothing. In this reasoning, agglomeration and lock-in characterize ICT while at the same time ICT contributes to overall economic growth. Again, then, growth brings greater inequality.

The description here, admittedly, emphasizes more certain parts of ICT than it does others. Some readers might question whether computer hardware manufacturing, say, displays the same increasing returns nature as computer software. I have chosen nonetheless to proceed broadly as in the text for three reasons. First, software is only the extreme case of many other high-tech products where intangible ideas are accounting for progressively more of the economic value than is the physical material hardware—mobile telecommunications products, network infrastructure, financial and entertainment content, and so on all show the same essential dematerialized, weightless properties. Second, in the computer industry, of software, hardware, and services, it is the first that is the fastest-growing and thus will be most important. Third, the concept of increasing returns is often used even in non high-tech sectors—see e.g., Krugman (1991a) and Section 2.2 below—just to begin the analysis of economic growth and geography: there is nothing special about applying it to computer hardware.

This set of apparently disparate ideas thus connects ICT development, growth, and economic inequality—inequality across space in particular. Combining them, one is led naturally to ask if rapid developments in computer and communications technologies are driving overall economic success in the US; whether these developments are leading to the US's economic performance leaving behind the European Union (EU) and all other countries in the world; whether spatial agglomeration within nations is integral to ICT success; and what policies towards technology and clusters are appropriate to economic growth and social cohesion as ICT continues to advance. Such questions encompass concerns about inequality at all levels: international, regional, and individual. The concerns are long-standing; the additional issue here is whether ICT magnifies the tensions between inequality and growth.

However, a further set of issues—although relatively unexplored still—makes ICT's role in growth and agglomeration especially intriguing. ICT differs from being just yet another industry that is high-tech and displays increasing returns. Two differences seem to me key.

First, ICT output typically has little physical manifestation—computer software is the quintessential example. That the output is intangible is, by itself, not particularly significant: haircuts and janitorial services are also intangible, but understanding their impact on agglomeration and growth is not difficult.

Where ICT differs conceptually is its putative disrespect for geographical distance, a feature not shared by many other industries where output is intangible. This then is a first critical distinction. In principle, ICT goods and services can be transmitted costlessly, without physical degradation, over arbitrary distances: Transportation costs do not matter. Internet transmission, wireless or otherwise, makes possible the most extreme spatial dissemination of work inputs and output distribution. That this must influence growth and geographical agglomeration seems clear; how exactly it does so is less obvious.

Second—again unlike janitorial services—the intangible output from ICT is *non-rival* or *infinitely expansible*. Think of computer software. Once located on a network or satellite server, its use by one consumer detracts not at all from its use by yet a different consumer. In this, ICT output behaves like knowledge (Arrow, 1962) or intellectual assets more generally. It is not just that scientific knowledge is an input in ICT production, but ICT output itself acts like knowledge. (Music and video entertainment and much other media content all are similarly infinitely expansible, and are typically not considered scientific knowledge either.)

What has been just described—the "weightless" properties of the ICT sector—applies in an extreme for computer software and media content. While not literally true for other ICT goods, services, and activity, they provide a useful organizing framework for thinking about the sector.

This paper provides an overview of the evidence—empirical and theoretical—on these questions, relating ICT to economic growth and spatial agglomeration. Looking ahead, some of the paper's conclusions are as follows: While, as widely thought, in ICT the US is ahead of the EU in many ways, in a number of significant dimensions, parts of the EU more than match the US. Clustering in ICT businesses and activity is pronounced within the EU, but whether significantly more or less than within the US remains to be studied. US regional evidence suggests, however, that geographical clustering in ICT activity is due more to two features of ICT, its drawing on a highly-skilled labor force and its being a fast-growth activity, rather than to anything intrinsic to ICT itself. Put differently, there is nothing special about ICT's spatial clustering: other industries with similar skill and growth profiles will also be similarly concentrated. Some relatively low-tech manufacturing in the US is more spatially concentrated than ICT activity, although media content production does almost invariably entail high concentration and spatial inequality.

The remainder of this paper is organized as follows. Section 2 discusses, in a little more detail than available above, the relation between technology, growth, and inequality in general, but spatially in particular. The goal is not to repeat discussion elsewhere but to highlight those features salient to the current analysis. The discussion is mostly conceptual. Section 3 presents empirical evidence on ICT activity in the EU and elsewhere, and relates those facts to the ideas discussed in Section 2. Section 4 attempts to answer policy questions on ICT development and social cohesion in the EU. Finally, Section 5 concludes.

2 Economic growth and agglomeration: Theory and general evidence

When economic growth was understood as just the accumulation of physical capital (Solow, 1956), the inequality and policy implications were direct. Those individuals, regions, and countries that had more physical capital were richer; investing in machines, buildings, roads, bridges, and factories was the route to prosperity. If there were impediments to accumulating physical capital, remove them. By force or reward, strengthen incentives to save and invest. Historically, this view informed policies ranging from Third World economic development—across varied experiences such as India and Singapore—to Joseph Stalin's experiments with building steel factories in a competitive race with the capitalist west.

2.1 Endogenous growth: Technology, increasing returns

When endogenous growth theory challenged this conventional wisdom, disputing the significance of physical capital, research effort shifted to *total* or *multi factor productivity* (TFP or MFP). Previously, TFP had been taken to be just a nuisance residual or a measure of the analysts' lack of understanding. Now, it is the engine of economic growth.

To see this more formally, suppose aggregate output Y obeys the production function

$$Y = F(K, N \times A), \tag{1}$$

where F is increasing and concave, K denotes the stock of physical capital, N denotes the quantity of labor employed, and A the residual factor needed to make (1) hold, given what we observe for Y, K, and N. The term A has an interpretation as the *state of technology*; it is this that is TFP.

An opposing view, as mentioned earlier, holds that A is merely a residual from econometrically fitting the production function (1). It would then be misleading to consider A as technology, in turn driving economic growth. The intermediate position is that A might well be comprised mostly of technology, but other determinants shape A as well. In particular, any institutional feature of an economy that interferes with the efficient use of factor inputs could well be part of A. The difficulty with this view is that it is unclear why these other features necessarily lead to A increasing steadily through time when economies grow—as happens naturally if A is technology.

Write $y = Y/N$ for labor productivity or output per worker and $k = K/N$ for the capital-worker ratio. Then provided that F satisfies constant returns to scale, equation (1) implies

$$\dot{y}/y = (1 - s_K) \times \dot{A}/A + s_K \times \dot{k}/k, \\ \text{where } s_K = K \times F_K/F \text{ and } F_K = \partial F/\partial K. \quad (2)$$

With factor markets competitive, the term s_K is physical capital's income share. Over long timespans, s_K has been roughly constant at approximately 40%. Equation (2) decomposes growth in output per worker into contributions due to technology and to physical capital.

While TFP has always been present in economists' thinking, early attention focused on the second term on the right of (2)—the contribution of physical capital—with TFP left unspecified. But even as early as Solow (1957), the simplest versions of (2) already showed $\dot{A}/A$ to contribute up to 90% of growth in output per worker, with physical capital accounting only for the remaining one-tenth.[1] More

[1] Given this imbalance, the economics profession in the 1960s and 1970s responded, not by re-orienting focus onto TFP's 90% contribution, but instead by attempting to re-measure and re-define variables to reduce its significance (see, e.g., Keely and Quah, 2000). But if capital has its units re-defined to include technological improvements,

recent contributions—e.g., Romer (1994) and Lucas (1990)—carry out yet other suggestive calculations to show that understanding A is critical for understanding economic growth.[2]

The most convincing models of TFP suggest that TFP either reflects increasing returns in the economy or represents the outcome of science and R&D, i.e., of advances in knowledge accumulation and engineering (e.g., Aghion and Howitt, 1998; Grossman and Helpman, 1991; Romer, 1986, 1990). While the two possibilities are not logically inconsistent, they can be conceptually distinguished. Increasing returns might arise from just externalities or simple Marshallian economies of scale, not science and technology. Improved engineering technology might just mean better physical machines, each used in isolation, with no scale effects resulting. Most researchers, however, follow Romer (1990), and suppose that technological change evolves endogenously due to an economic activity—namely R&D—that involves increasing returns.

With increasing returns, economic activity can display technological lock-in (Arthur, 1994; David, 1985): Once a certain technology establishes a beach-head presence, every individual producer or consumer finds it unprofitable to switch technologies, even after a socially preferred alternative becomes available. This is not to deny that a sufficiently superior technology can displace older inferior ones, only to say that there might be socially inefficient thresholds—arising endogenously from the decisions of people and businesses—that need to be overcome before that substitution can occur.

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or labor is re-measured to incorporate increases in knowledge, what are those changes but technology? The more recent, arguably now-mainstream interpretation of A as TFP recognizes the early Solow (1957) measurements to be likely the right ones, and identifies successful economies as economies that show large, significant A's, for these are the economies with high productivity.

[2] Quah (2001a) summarizes those arguments. Not all researchers agree on the importance of technology as thus described. Opposing perspectives are given in, for instance, Jones (1995) and Mankiw et al. (1992).

2.2 From growth to clusters: Economic geography

New economic geography (Fujita et al., 1999; Krugman, 1991a) exploits the same insights, now not dynamically or in the space of technologies, but instead across physical space. Regional specialisation in specific industries, the evolution of cities and urban systems, and geographical agglomeration more generally, become the objects of analysis, but the central underlying ideas remain those of increasing returns or technological lock-in.

If, whether by historical accident or coordinated expectations, one geographical region becomes specialized in, say, button manufacturing, then increasing returns to scale implies that button manufacturers find it especially advantageous to cluster there, and will continue to do so even as the economic and technological landscape changes about them.

As described here, these spatial clusters can be in just a single industry, not necessarily an entire spectrum of inter-related activities. Thus, these ideas, while related to those in Porter (1990), are simpler, if more rigorously formalized. Porter's descriptions invariably involve essential intricate connections and complex inter-relationships across entire production chains. Richer models, such as Venables (1996), make those inter-connections available—the point, however, is that, in the new economic geography, spatial clustering and agglomeration can arise even absent those linkages.[3]

In the theory, geographical agglomeration emerges as an equilibrium outcome to resolve the tension between centripetal and centrifugal forces. The former leads to economic activity concentrating in space; the latter, to its dispersing. As described thus far, with increasing returns to scale, only centripetal forces manifest. To understand ICT's impact on geographical concentration, we now describe

[3] Le Blanc (2000) has studied how, in the US, across states, Porter-type co-location mattered for employment growth in the 1990s in the information technology industry. In the current paper I focus on the more stripped-down concept of agglomeration, to keep distinct the different notions of clustering.

centripetal tendencies more explicitly, then add in centrifugal forces, and finally analyze how ICT affects each of them in turn.

Following the exposition of Marshall's ideas in Krugman (1991a, Ch. 2), most researchers have considered the problem of a firm making a choice on where to locate. The firm faces three potential sources of centripetal forces: pooling of skilled workers, availability of specific intermediate goods and services, and knowledge spillovers. For the purposes here, we can group together skilled workers and specific intermediate goods and services into just one category, specialized factor inputs. The term *knowledge spillovers* is shorthand for the presumption that ideas travel better locally than they do globally: Marshall's "mysteries of trade ... in the air" (Krugman, 1991a, p. 37) are specific to particular locations.

Describing the economic problem as one where a firm seeks to locate somewhere imposes immediately an implicit assumption of increasing returns. Under constant returns to scale, firms don't need to locate anywhere; they can chop up operations arbitrarily finely, and locate instead everywhere. It is only with increasing returns that a single large operation works more efficiently than many small ones—a firm seeking to place its operations in one location reflects an extreme version of this effect. And, with increasing returns, factor inputs are better compensated going where businesses happen to be more concentrated.

We will return to knowledge spillovers in Section 2.3 below, but turn now to centrifugal forces. There are three obvious considerations. One, output must be transported from where it is produced to where consumers wish it. This can be costly for bulky products: output (like, say, icebergs) can deteriorate from transportation. Thus, if consumers are dispersed, then other things equal, production will attempt to locate similarly. Two, areas that are relatively underserviced enjoy higher demand. Or, put differently, over-serviced areas see greater price competition in the market for industry's output. Thus, again, if transportation costs matter and consumers aren't clustered, production will tend to disperse. Three, high concentration engenders congestion: Rents and wages rise; the environment deteriorates.

The first two of these considerations hinge on transportation costs. Without such costs, some of the strength of the centrifugal forces should disappear. In the theory, geographical clusters emerge to balance the tradeoff between centripetal and centrifugal forces.

2.3 Knowledge spillovers

The assumption that technology or knowledge spillovers are localized contrasts with an assumption typical for studying economic growth across countries. In the latter, "'Human knowledge' is just human, not Japanese or Chinese or Korean" (Lucas, 1988, p. 15), and thus specific to neither location or country.

But, if we identify technology with knowledge, economists' views differ on its location-specificity: Coe and Helpman (1995) evaluate cross-country technological progress by relating R&D to domestic and foreign productivity. They find that large and significant cross-economy spillovers occur, mostly through cross-country trade; however, technology levels certainly remain country-specific.[4] Jaffee et al. (1993) use patent-citation microevidence to show that geographic localization of scientific knowledge spillovers is considerable in US metropolitan statistical areas. Thus, empirical evidence suggests that knowledge and technology—codified in R&D and patents—do spread, but only incompletely and gradually, not fully and instantaneously.

In contrast to this work, analyses such as in Lucas (1988) take country-specific technology levels to denote instead human capital, thereby assuming technology to be embodied in labor. Technology is then specific to individual economies as long as labor remains immobile. But even if knowledge embodied in human capital were to spread through cross-country spillovers, its dissemination mechanism must necessarily differ from that for the codified knowledge described by R&D or patents.

The distinction corresponds to a similar one between tacit and

[4] Keller (1998) disputes the first of these statements: he argues that whatever mechanism it is that brings about cross-country technology dissemination, it is not international trade.

codifiable knowledge (e.g., David, 1992), although here the margin between embodied and disembodied must, to some degree, be an object of choice. What is embodied in human capital might well be codifiable, and thus made disembodied. Developing economies might, for reasons of relative price, choose to contain codifiable knowledge within human capital, while richer economies choose the opposite, to preserve scarce, expensive leisure time and, instead, save codifiable knowledge as disembodied blueprints.

2.4 What have we learnt?

How useful are the preceding ideas for analyzing ICT clusters in particular or high-tech clusters more generally?

Krugman (1991a) emphasizes that the centripetal and centrifugal forces in economic geography are not specific to technology-intensive activity. He describes geographic concentration in activities as diverse (and low-technology) as carpet manufacturing, jewelry production, the shoe industry, and the rubber processing industry. Industries localize, even (or perhaps especially) in sectors that are far from high technology. Devereux et al. (1999) document that for the UK the most spatially agglomerated industries are relatively low-tech.

Across countries, the distinction between high-technology and low-technology is not typically explicitly considered. More common, as just described above, is distinguishing the technology embodied in human capital from that codified in patents and R&D.

I take two lessons from this review of earlier work to inform the subsequent discussion on growth and agglomeration. First, ICT influences the balance between centripetal and centrifugal forces. Second, distinguishing different kinds of technologies matters—even within only high-technology sectors. In cross-country economic growth, the dissemination mechanisms vary, depending on whether the high technology being considered is that codified in R&D and patents or that embodied in human capital. Similar differences will therefore figure in clusters and agglomeration.

3 ICT in growth and agglomeration

ICT is not just high technology. It is high technology with significant and peculiar properties.

ICT is sometimes portrayed as skills-biased, and an instance of a general-purpose technology. If so, however, those features are shared by other technologies, and so ICT is not special in either regard. Moreover, a priori, it is debatable whether ICT is more skills-biased than many other technological improvements. For instance, the whole point of developments like windowed graphical user interfaces is precisely to lower skill thresholds for manipulating information on computers.

Two other features, instead, seem to me key for analyzing ICT. First, many ICT products are, in the main, disrespectful of physical distance and geographical barriers. Transportation costs are irrelevant. Why then clusters, or more specifically, why then particular patterns of location in ICT activity—not just total randomness or, the other extreme, complete concentration and agglomeration?

Second, ICT products show, moreover, the same infinite expansibility or nonrivalry displayed by intellectual assets generated by R&D and typically protected by intellectual property rights (IPRs) such as patents. However, such ICT output is unlike many R&D-produced, patent-protected intellectual assets in two respects (Quah, 2001c): First, it is not usually an input into a further production process, but instead directly used by the consumer. Second, it is typically not protected by patent, but by copyright. Computer software displays both these features. In this respect, the ICT sector can, potentially, differ in its behavior from the localized, gradual spillover dynamics documented in Coe and Helpman (1995) and Jaffee et al. (1993).

The Internet is a medium by which these features—the disrespect for geographical barriers and the tenuousness of standard IPR systems—become especially pronounced.

3.1 Death of distance in economic geography

Internet development alters the balance between centripetal and centrifugal forces for key (and perhaps most important) ICT sectors.

Transportation costs for output delivery no longer vary in physical distance. Either the customer is on the Internet, or is not. Consumers off the Internet are effectively out of reach, so that transportation costs for them are infinite. When they are on, however, transportation costs are zero, so that centrifugal forces decline dramatically. Thus, as Internet access grows, centrifugal forces progressively fall. Other things equal, there should then be *increasing* spatial agglomeration of ICT production.[5]

The opposing view describes incipient decline in centripetal forces. As Internet and telecommunications infrastructures improve, workers no longer have to be together in one physical place for certain collaborative communications. This hypothesis allows some communications still to be better achieved face-to-face; it just does not require that all be so. The hypothesis bears most centrally on that centripetal force described by Marshall's "mysteries of trade in the air". It implies a weakening of such knowledge spillovers, and so, other things equal, predicts *decreasing* spatial agglomeration.

An implication distinct from both centripetal and centrifugal force reasoning is that, for global location, timezones might come to matter progressively more, and physical distance not at all. Conditional on natural geographical variation in climate and land, clusters form within distinct time bands on Earth, with latitudinal information irrelevant. Quah (2000) provides, as far as I know, the only formal discussion of such effects: He shows how timezone clusters can arise from dynamic collaborative production activity. The analysis, however, is entirely conceptual, with only impressionistic empirical evidence on the effects studied.[6]

[5] The Silicon Valley phenomenon—as described, say, in Saxenian (1994)—is typically thought to illustrate this.

[6] Cairncross (1997) explores the same possibilities in a more wide-ranging but less formalized way.

Kolko (2000) considers the distribution and geographical dynamics of Internet industries in the US. He notes that the concentration and persistence of locations like Silicon Valley might reflect not just ICT's unique features, but instead simply the high-skilled, fast-churn nature of that industry—characteristics shared with many other industries. This is not to say that high skills and rapid turnover directly explain concentration and persistence, but that ICT is no different from other industries in showing slow-changing clusters of activity.

Using cross-region growth regressions, Kolko (2000) establishes that after conditioning on the skills mix and high birthrates of firms in Internet industries, it is *centrifugal* forces that are more pronounced. This result is an empirical regularity; the mechanism whereby high skills and rapid turnover lead to persistent clustering remains to be studied. Conditional on that, however, one can conclude tentatively that clusters are relatively less likely to remain for Internet (and by extension other ICT) industries. Instead, the economic landscape will tend to become progressively less agglomerated.

3.2 ICT Clustering across the EU and elsewhere

On larger geographical scale, we can also assess the degree of ICT clustering across countries and within the EU.

The definition of ICT used here is given in OECD (2000, p. 7), and comprises segments of both manufacturing and services industries. In manufacturing, to be included, the industry must either perform information processing and communications or use electronic processing to measure or control a physical process. In services, the industry must enable information processing and communictions by electronic means. The definition includes six ISIC 4-digit codes for manufacturing and four ISIC 4-digit codes for services. Notable among these is ISIC 3000 (Office, accounting, and computing machinery) from manufacturing and ISIC 6420 (Telecommunications) from services, as well as TV and radio equipment and receivers and computer- and related activities across a range of ISIC codes.

In 1997, in the EU the fraction of total business employment in ICT industries matched that in the US: Both equalled 3.9% (Koski et al., 2000; OECD, 2000). This means, however, that a select group of EU member states had ICT employment concentration *higher* than the US: Sweden, 6.3%; Finland, 5.6%; Denmark, 5.1%; the UK, 4.8%. Low ICT employment EU member states included Portugal (2.7%) and Germany (3.1%).

Overall ICT productivity is considerably higher in the US. In 1997, ICT contributed 8.7% of total business valued added in the US, but only 6.4% in the EU—a ratio of 1.4. In the EU, the greatest ICT fraction of value added was in Sweden (9.3%), the UK (8.4%), and Finland (8.3%), while the lowest in the Netherlands (5.1%) and France (5.3%). (Figures were unavailable for Ireland, certainly a candidate for the high end of the value-added range.)

Not unexpectedly, US R&D spending in ICT industries as a fraction of total business R&D expenditures exceeded that for the EU—in 1997, the former spent 38.0% of total business R&D on ICT, the latter only 23.6%, a ratio of 1.6. Several EU member states, however, devoted proportionally more R&D spending to ICT than did the US: Highest was Finland (51.0%), followed by Ireland (47.7%). Lowest ICT R&D member states were the Netherlands (19.6%) and Germany (20.1%).

A remarkable fact emerges in the trade balance statistics (Koski et al., 2000; OECD, 2000). Popular impression has it that because the US is such an ICT powerhouse, it must export ICT to the rest of the world on net. In reality, in 1998 the US was a net ICT *importer* by 35.9 billion USD. Ireland, instead, is that country whose ICT exports exceeded imports by 5.8 billion USD; Ireland is the economy with greatest ICT trade balance among the US and all EU member states. Finland and Sweden, with 3.6 billion USD and 2.8 billion USD net ICT exports, similarly had ICT trade balance greater than the US.

Different reasons might, of course, explain this. US consumers might demand proportionally more ICT than EU consumers, suggesting that part of the reason for US success could be its strong demand base (Quah, 2001b,c). Outsourcing along different parts of the ICT value chain might have led lower valued-added production to locate outside the US: Note, however, that the ICT trade numbers are in terms of *value*, not volume. Even if it were only very low value-added work moving outside the US, enough of it occurs, evidently, that the value adds up to be significant.

Closely related, the deficit numbers likely reflect nothing more than comparative advantage along different parts of the ICT value chain. If so, the picture that emerges of ICT success is one of diversification, specialization, and exploiting comparative advantage. There is no one model of ICT-driven economic success.

Finally, ICT might now be too large a segment to be economically meaningful: Telecommunications expertise and comparative advantage in the EU might overwhelm the information technology part of ICT trade. But if so, then that obviously matters too, so the ICT net trade numbers meaningfully and correctly show that. This reinforces the conclusion that diversity and comparative advantage matter—in ICT as elsewhere.

3.3 Big blocs, small blocs

An important lesson emerging from this discussion—the trade balance statistics, in particular—is that ICT success in countries is difficult to assess reliably. Few doubt that the US is a successful ICT economy. Yet its international trade position in ICT might suggest otherwise to a casual observer.

Similarly, examining ICT success (or failure) in the EU as a whole disguises smaller-bloc pockets of excellence—in Ireland, Finland, Sweden, and, to a lesser degree, the UK.

Fig. 1 shows, from Koski et al. (2000), the 1999 spatial distribution by postal code of over 11,000 ICT businesses across the EU. Two geographical agglomerations are prominent. First is a large central crescent, beginning in London in the west, proceeding counterclockwise via Randstad in the Netherlands through industrial areas in German, Switzerland, and northern Italy in the east and south. Second is a smaller Nordic pole, covering the metropolitan areas of Helsinki and Stockholm, and comprising primarily mobile and telecommunications activity.

Fig. 1 gives the stylized impression of significant clustering about the major European urban centers. However, not all urban centers see associated ICT activity, nor do all clusters surround only cities. Further, the crescent concentration proceeds in a way that practically ignores EU member state boundaries—national borders seem entirely permeable in that geographical sweep (Quah, 1996). Is this spatial pattern unique to ICT? Does this pattern show ICT merely mirroring urbanization across space? Thus, would, for instance, the spatial sweep of hairdresser activity look markedly different?

Tracing through these connections and understanding the dynamics of emerging ICT development must consitute research that remains high on the agenda. However, even now, we can see that studying those dynamics at only national levels is likely to miss critical elements of what is important.

3.4 Inequality

The final set of questions I consider abstracts from the fine details of agglomeration across economic units but treats directly the dynamics of inequality.

Whether it is increasing returns or technology spillovers that matter, if ICT magnifies their effects, then inequality must be increasing with ICT's increasing pervasiveness. Moreover, how these effects matter—at location, city, region, country or individual level—is potentially the same. We can thus gauge ICT's impact on inequality by looking at a range of evidence, at varying levels of disaggregation.

Across countries, inequality has been increasing steadily since 1960 (see, e.g., Quah, 2001a); inequality across EU regions, similarly, over all of the 1980s (Quah, 1997). While ICT has been studied as a leading cause of increasing wage inequality across US workers, its impacts in micro data remain controversial (Autor et al., 1998; DiNardo and Pischke, 1997; Krueger, 1993). However, over long time periods at an aggregate level, US family and household income inequality have been steadily rising since the late 1960s and early 1970s (Wolff, 2000). Two factors account for most of this: unemployment fluctuations and deunionization. Wealth inequality, measured as the fraction of wealth owned by the top 1% of US households, has been rising steeply since the mid 1970s, from a low of 22% in 1976 to 38% in 1998. The high inequality in 1998, however, only matches its level from 1965. From 1965 through the low of 1976, wealth inequality practically halved; before 1965, it had been constant for at least a decade. Over this entire timespan, changes in wealth inequality have been due primarily to movements in the stock market and house prices.

By contrast, changes in economic performance from ICT in the US are only observable, if at all, from the mid 1990s (Gordon, 2000; Oliner and Sichel, 2000), a full three decades after inequality had already begun to rise. Inequality cannot have risen ahead of time in anticipation of ICT's impact. This does not say, of course, that ICT cannot have exacerbated the already rising inequality. But it does say that many other factors have mattered importantly.

To emphasize this, regression of the critical stock market/house price measure on ICT variables achieves an R^2 of no more than 50% (Wolff, 2000). When both asset prices and ICT indicators enter the right hand side of a regression explaining wealth inequality, it is only asset prices that matter: ICT indicators are invariably insignificant.

To summarize, for economic units ranging from countries to individuals, inequality has increased, almost uniformly throughout the world. However, this rise of inequality began long before ICT developments took hold. There is thus little evidence in the data over longer stretches of time that recent ICT progress has been at all critical to increasing inequality.

4 What should Europe do?

If increasing returns and endogenous technical progress are central to economic growth, spatial clusters too must be important—the same forces that drive growth generate agglomerations in space. But this statement applies independent of whether we are analyzing carpet manufacturing or ICT. Put differently, nothing special about new technologies is implied by or central to the conclusion. More to the point, however, the statement speaks only to the presence or absence of such forces. Whether the forces are quantitatively dominant is an empirical question, not a theoretical one.

What makes ICT different from other technologies is important, and understanding that must be critical to policy formulation. Theoretically, "death of distance" and "weightless economy" effects, taken together, can predict either greater or less spatial clustering. Empirically, the evidence suggests greater dispersal of economic activity—lower regional inequality—is likely.

What concentrations succeed seem to do so at finer levels of disaggregated economic decision-making than the nation state. Policy, therefore, might need to focus on regional levels rather than national. The idea that entire nations should concentrate on ICT for successful economic growth is a myth. Even the US is a net importer of ICT. Moreover, successful regional clusters seamlessly propagate across national boundaries in the EU.

Although not central to the current discussion, the analysis above has also pointed to how systems for managing intellectual property—incentives for their creation, simultaneous with mechanisms for their widespread dissemination—will be critical.

Finally, as in any other knowledge-intensive activity, local education and research and development are key to successful economic performance in the ICT sector. This will be true as long as tacit knowledge, human capital, and even codified ideas remain localized. In ICT, those impacts are magnified as skills and sophistication matter not just in production but also consumption (Quah, 2001b,c).

5 Conclusions

This paper has addressed some broad implications of ICT developments on agglomeration and economic growth in Europe.

Is economic growth in Europe diverging? Do agglomeration effects from ICT mean that inequality is increasing across regions and countries in Europe?

This paper has pointed to how the same factors—increasing returns, technology spillovers—underly both economic growth and spatial agglomeration. We therefore cannot rule out the possibility that we have to answer yes to the policy questions above.

What is the evidence on whether ICT has brought about increased inequality in the EU? The answer here has to be no. ICT has certainly begun to contribute positively to EU economic performance. But it has done so in local agglomerations and clusters, almost independent of the configuration of nation states. Moreover, many other factors appear to influence inequality, and, for the time being, have been more important than ICT.

It is a myth that all nations need to develop ICT similarly for successful economic growth. Two observations help us appreciate this. First, even the US is an ICT net importer. Second, it is regions that form successful clusters seamlessly across national boundaries, not regions that lie entirely within a given nation.

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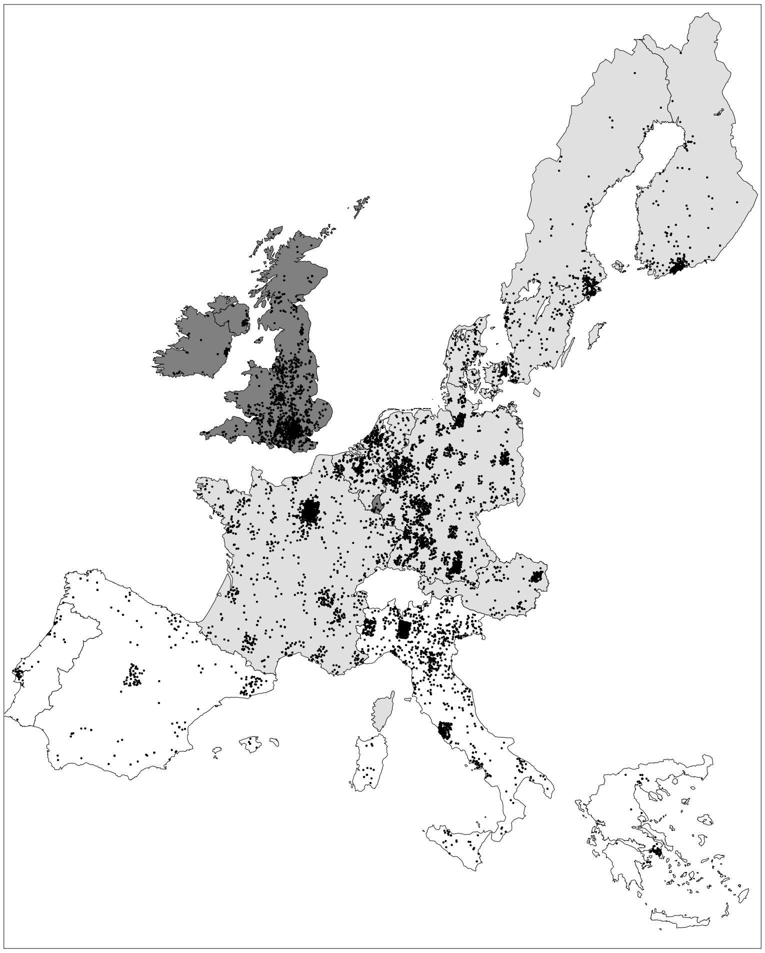

Fig. 1: ICT business activity across the EU (From Koski et al. (2000) and `www.europages.com`) Over 11,000 ICT business establishments are displayed, each establishment producing a dot in the map, appropriately located within postal code. EU member states are shaded by ICT concentration: dark grey (over 4% of non-distributors/non-retailers are ICT firms); light grey (2.5–4%); and unshaded (less than 4%).