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Regional Specialization, Local Externalities and Clustering
in Information Technology Industries

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Abstract: Is there a 'new' economic geography of Information Technologies driven industries? Does the fast growth of the Digital Economy shape new regional specialization and industrial concentration? How do the different theories of agglomeration externalities contribute to the understanding of clustering dynamics in IT industries? This paper uses geographical data from 1992 and 1997 Census to examine spatial and regional growth patterns of the Digital Economy in the United States. We argue that the regional co-location of the distinct industries (telecoms, software, Internet services, media) making the Information economy, but not their separate regional specialization, encourage employment growth. This 'convergence' process helps explaining the emergence of new IT-specialized clusters, amid the traditional high tech States. It also gives some economic substance to the common place idea of IT convergence, which is often solely considered under the technological or business dimension, and presents it as a particular case of Jacobs' dynamic diversity externalities.

JEL Classification: L10, R30, O30, L86, L96

Key words: specialization, clustering, agglomeration externalities, IT industries

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1. Introduction

Although the theory behind it still remains incomplete and unsatisfactory, the prevalence of geographical specialization is for sure one of the most spectacular stylized facts of the real-world economy. In the US, everyone would for example immediately associate the car industry with Detroit, movies production with Hollywood, aircraft manufacturing with Seattle, defense and microelectronics with California and so on. At the country level, specific policies labeled as regional development, structural cohesion or country planning are precisely set up to address the economic and social consequences of such specialization: disparities between regions, between metropolitan and rural areas, and even sometimes inside cities. In academic research, there has been in the last few years a spectacular renewal of interest in the economic theory of local specialization and growth. A new literature developed on this classic but somehow neglected topic, with many innovative contributions, such as the emergence of a 'new economic geography' (Fujita, Venables, Krugman, 1999), the breaking down of the dynamic components of agglomeration externalities (Dumais, Ellison, Glaeser, 1997 ; Henderson, 1999) or the revival of the industrial district's idea in an information economy (Porter, 1998).

The amazing growth of the Information Technology (IT) industries making the Digital Economy¹ offers in this context an exciting 'natural experiment' and an appealing opportunity for revisiting alternative theories of industrial location, regional specialization and local clustering. First of all, what we call IT-related Industries such as Telecommunications, Software, or Internet Services, could be strictly considered as disrespectful of geography in the traditional sense. However, various case studies and regional data on employment in the US show that these industries exhibit a high level of geographical concentration. Interestingly enough, we also have empirical evidence of the emergence of brand new IT industrial clusters (e.g. in Virginia, Colorado, Delaware), amid the traditional high-tech States specialized in Software, Electronics or Biotechnology (California, Massachusetts). Even in a world where transportation and communications costs keeps on decreasing, location still matters. But how can one then account for regional specialization in the Digital Economy? And, to which extent do the alternative theories of agglomeration externalities apply to the IT sectors?

Very little has been said so far about the specific geographical patterns of the Digital Economy. In fact, because of the lack of consistent and relevant statistics, research efforts logically first concentrated on the overall evaluation of the economic and financial weight of Internet-related activities (e.g. in 1999, the US Department of Commerce report *Emerging Digital Economy II* or the CREC study on the *Internet Economy Indicators* at the University of Texas). These macroeconomic overviews measure classic aggregate variables (production, added value, investment, employment, growth) in the IT sectors but without any geographical distribution. Besides, the latest comprehensive statistical survey on the US economy (*Economic Census*) available until the end of 1999 was dating from 1992, i.e. several years before the diffusion of the World Wide Web as the universal navigation tool on Internet for millions of users and the fast growth of electronic commerce. This meant that data on a crucial segment of the

¹ We adopt on purpose in this paper the Digital term instead of the common Internet, IT or New Economy names to underline that the numerization of information to process, transmit and store it is actually the main engine driving the structural changes transforming our economy (see Bomsel, Le Blanc, 2000).

Digital Economy (Internet service providers, portals, electronic financial, security or certification services, etc) is missing. The regional implications of the structural change driven by the Digital Economy have therefore not been systematically investigated (the issue is mentioned in a very indirect way - focusing on negative disparities rather than positive features - in the various appraisal of the 'Digital Divide' in the US).

Existing information is limited to qualitative ranking of the US states according to different variables supposed to capture the main patterns of the new economy (Atkinson, Court, 1999), or sector data on jobs, turnover, exports gathered at the state level by professional bodies such as the American Electronics Association (1999 *Cyberstates 3.0*). One should also mention the great number of management studies devoted to the new firms of the Digital Economy that underline the very close link between the company and its city of origin: Amazon in Seattle, Dell in Austin, AOL in Virginia near Washington... Despite their informative interest, these stories only focus on one or two exemplary companies and tell us very little on the local industrial structure, the former and existing specialization, inter-firms links... Moreover, it would be quite risky to derive any generalization from some isolated special cases. By examining the State specialization in IT industries, this paper aims at filling the gap between fragmented company cases and aggregate macro evaluations.

In Spring 1999, an extensive fieldwork survey in Denver (Colorado) on the telecommunications industry first suggested that the forces pushing for agglomeration not only arise from increasing returns (such as in the Marshallian tradition extended by Arrow and Romer) but also from the local complementarity between different IT industries. It actually emerged that what we initially considered as a telecom cluster is in fact not restricted to one sector or industry, but rather includes several IT industries (telephony, cable, software, Internet services, data processing). This suggests a specific class of agglomeration externalities, which do not operate within an industry but between different industries, and are usually known as Jacobs diversity externalities (from Jacobs' 1969 pioneering work on the determinants of cities growth). In a similar way, the Denver case appears quite different from the traditional models of industrial districts, where the competitive advantage come from labor market proximity and flexibility (the textile Italian cities) or top University and research environment (the Silicon Valley). From these empirical observations, we derived the 'convergence' hypothesis, which states that the new linkages between telecoms, computer and media industries support new agglomeration externalities, and correspondingly new industrial clustering and regional specialization. This paper builds on this initial intuition and uses recent data from the 1997 Economic Census to test it in the U.S. case.

The first motivation of this research is to get a better understanding of regional patterns of the Digital Economy and to contribute that way, with a new applied case, to the current economic debate on the source and scope of agglomeration externalities. Our second motivation comes from a larger research prospect dealing with competition and market structure in the Digital Economy. It actually turns out that the main engine driving the growth of Internet and electronic commerce is the transformation of a mono-product (telephony) network into multiple interconnected networks, upon which many goods and services of different nature - data, voice, music, video - are transmitted. However, the radical economic consequences of such situation are yet to be systematically explored. This is where comes the widely found idea of convergence, supposed to capture the entire story. Of course, the technological side of the process is extensively studied and supports quite convincingly the concept of convergence: demonstrating how voice telephony might be transmitted over the Internet, Internet on

cable networks, or high speed services such as video on an ordinary residential copper line... But a proper economic content of this convergence is clearly lacking. It is nevertheless regularly put forward to explain and justify the on-going wave of mergers in IT industries these last few years (in particular the recent merger between AOL and Time Warner presented as the paradigmatic convergence case). In the present lack of rigorous and homogeneous data at the industry or firm level, we find it necessary to make a detour at the regional level (state in the US case), to rigorously determine the existence and magnitude of the convergence between different IT industries. Once significant evidence have been assembled, it could then motivate and justify future research on the IO foundations of this convergence process and how it translates at the market and industry level. Hence the two questions discussed in this paper are the following:

- What are the effects of convergence between these industries on local growth and specialization? Does it correspond to the emergence of new industrial clusters? Which theoretical models help explaining the econometric results?
- What is the relative weight of the different agglomeration externalities in ‘digital clusters’: localization, urbanization, scale & scope economies, input sharing, technological spillovers?

Section 2 presents the different theories of agglomeration externalities and regional specialization, emphasizing their differences according to the source, the scope and the conditions strengthening local effects. Section 3 describes the data, our definition of IT industries and the geographical specialization variables used. Section 4 presents the overall 1997 picture of regional IT specialization in the U.S. Section 5 tests the convergence externalities with alternative specialization and urbanization theories in fostering employment growth across State-IT industry between 1992 and 1997. Section 6 presents conclusions and possible research extensions.

2. Theories of Regional Specialization and Agglomeration Externalities

While the whole literature on agglomeration externalities stems from the shared need to explain the emergence and persistence of economic geographical concentration, it in fact encompasses quite different approaches and concerns. To simplify, one may distinguish three main strands:

- Geographical economy,
- Urban growth and specialization,
- Industrial clusters.

The first one deals with the economics of industrial location, the resulting regional differences in growth, productivity or employment across the country. Without directly addressing the question of why concentration occurs, it focuses on the reasons why it should persist, self-reinforce and increase, generating huge national discrepancies on observable parameters such as jobs growth, productivity or investment (Krugman, 1991a ; Rauch, 1993 ; Ciccone, Hall, 1996 ; Ellison, Glaeser, 1999 ; Fujita, Krugman, 1999). The second strand focuses on the city as the unit for analysis and tries to assess the emergence, the specialization and the growth patterns of cities (Jacobs, 1969 ; Henderson, 1988, 1999 ; Glaeser and al., 1992, Holmes, 1999). The final one directly consider what are referred as industrial clusters or districts to explore the determinants of their

success, and the reasons that lead firms to co-locate in a specific area (Porter, 1990, 1998 ; Saxenian, 1994 ; Roelandt, Hertog, 1998 ; Baptista, Swann, 1999).

These disparate approaches explain the somehow confusing diversity and heterogeneity of the vast literature on regional specialization and agglomeration externalities. As a matter of fact, depending on the case, these externalities will refer to a firm, an industry, the industrial district, the city, the metro area, the whole state, etc. Some papers might strictly consider the scale economies at the level of the individual firms, whereas some others discuss the overall benefits of local concentration and the corresponding competitive advantage for the cluster or the industrial district as a whole. Finally, many papers mix up in a puzzling way the investigation of externalities' nature and how they work, with the study of the factors reinforcing their magnitude. For these reasons, any reference to the literature of industrial clustering and economy geography should be cautiously used. To avoid any confusion, we first list the different types of externalities examined by the literature, before summing up the unresolved debate on which attributes of the local environment generate and increase externalities.

The easiest way to sort out the different agglomeration externalities is to take up Marshall's (1920) classic view on geographic concentration. Marshall argues that a firm receives three kinds of benefits by locating near other firms in the same industry: information spillovers amongst producers, more efficient labor markets, and savings in transport costs of suppliers' parts and distribution to retailers. Let's then consider three categories of agglomeration externalities: those directly impacting firms' productive efficiency, those related with the labor force, and finally the knowledge spillovers.

The first group includes local scale externalities mentioned by Marshall as a direct effect of industry concentration: the proximity of suppliers and customers or, in the modern vocabulary of development theory, the forward and backward linkages (Bartelsman and al., 1994). In its very basic formulation, this is the argument of natural resource advantage (whose decisive role in oil, coal or steel industries' location during the last century is well documented in Bairoch, 1988 and Chandler, 1978). In a broader perspective, transport costs induce firms to locate close to their input suppliers as well as their customers to reduce their shipment and distribution costs. This intense activity of local markets eventually gives rise to another external effect. A high local demand actually allows a greater number of intermediate inputs producers to break-even. And an increased variety of intermediate goods will in turn make the production of final goods more efficient (Krugman, 1991 ; Ciccone, Hall, 1996). In addition to that, the scale of existing local production of differentiated goods also increases enabling new scale economies through a second-margin effect (Holmes, 1999).

If we now turn to the labor market side, we find several converging external effects. The main one stressed by Marshall – labor market pooling - is that a large local base in a specific industry protects workers from business uncertainty and potential demand-shocks. The idea is that firm demand may wildly and suddenly vary, while industry demand commonly remains roughly

stable. Local industry concentration gives workers many other opportunities in case of layoff, without having to move away, nor losing their specific skills. They know that, if they lose their jobs, they should find easily new opportunities from nearby firms, in their very specific skills and qualifications, and without having to relocate. On the other hand, companies benefit from a large market of skilled and experienced employees and can therefore reduce their search and recruitment costs. Local industry success finally plays a major role in attracting and retaining trained and motivated young people (this point is of decisive importance in industries that face national and worldwide skilled labor-shortages such as most of the IT sectors).

The third group of externalities builds on the idea that geographical proximity facilitates and intensifies transmission of information (often called Marshall-Arrow-Romer externalities after the successive contributions from Marshall, 1920 ; Arrow, 1962 and Romer, 1986). These knowledge spillovers are particularly important in the technological field and may take many forms. Spying, imitation, business interactions, inter-firm circulation of skilled employees, informal exchanges, all this promotes the quick dissemination of innovation or ideas from one firm to the others, without monetary transactions (Saxenian, 1994).

For metering reasons, this last effect is however very difficult to assess empirically. However, several estimations suggest their importance. Ellison and Glaeser (1999) have for instance imagined an indirect method for evaluating them. They put together a set of variables, supposed to capture all sorts of natural advantages in industrial location (State structural characteristics, basic inputs costs, labor inputs, transportation costs...) and found that only 20% of geographical concentration can be attributed to these variables. They argue that the remaining 80% must be explained by knowledge spillovers.

All these kinds of agglomeration externalities differ in what they consider the source of externalities and which factors fosters their effects. One of the main divisions running through the literature opposes the localization to the urbanization theories, depending on whether externalities work within or between industries. In the first case, agglomeration externalities operate within an industry and are best stimulated by local own industry specialization (Henderson, 1988). On the opposite, the urbanization theory argues such specialization hurts and that the local external economies of scale are mostly achieved outside the home-industry through cross-fertilization (Jacobs, 1969). It then claims industry growth will first depend on the overall economic activity in the area, whose measure could be its absolute size, its density or the degree of industrial diversity). The form of externalities at work underlies opposite growth predictions. If localization externalities prevail in an industry, firms are likely to cluster in a few cities or regions, where the high geographical specialization will foster their growth. But in a context of urbanization economies, industries should need a diversified industrial environment to grow faster.

This distinction provides us with a nice model for testing the convergence in IT industries. This hypothesis actually assumes that local externalities first derive from the

proximity of several IT industries, which looks like a specific case of Jacobs diversity externalities. We will then study how the local IT industrial diversity explains the growth of a particular industry, in comparison with other explanatory variables such as this specific industry specialization or the cumulative local weight of IT-related activities.

The extension of the notion of geographical concentration beyond a single industry follows two different but complementary ways. The first one, which will prove quite relevant and useful for our topic, argues that an industrial cluster and its boundaries are defined in the first place by competition (Porter, 1990, 1998). Since there is no standard economic definition of a cluster, the identification and the lay out of a regional cluster is often a controversial and disputed issue. Rather than following a technological description, the successive transactions along the chain value or statistical classification, Porter draws the boundaries by searching the linkages across industries and institutions that are most important to competition. Hence he proposes an original definition of a clusters as 'critical masses in one place of unusual competitive success in one field'. Porter still retains the idea of local specialization 'in a particular field' as the foundation of a local cluster and the source of positive dynamic externalities. He however does not restrict it to a single industry and enlarge the scope to include vertically or horizontally related industries, supporting services and specialized infrastructure, all closely interconnected with the initial one through competition. Local scale effects and locational decisions are thus not restricted to the input cost dimension alone but take into account innovation, total systems costs, and the overall productivity gains achieved in being part of a cluster. Even in labor-intensive industries, Porter then argues that the vibrancy and the dynamism of the cluster could easily overturn a relative factor cost disadvantage.

The second approach emphasizes the role of technological change in leading firms to cluster together. Building on the evolutionary economics perspective, it uses at the regional level the concept of national system of innovation (Freeman, 1982 ; Lundvall, 1992) to suggest another widening of the cluster's scope. The cluster of manufacturers, services providers, and their suppliers encompass users (who are a major source of product or process innovation through so-called learning-by-using process) and many local institution (government, regional and city administration, universities, research centres, professional and trade bodies). Applying at the local level the same systemic approach of the innovation process developed by evolutionary economics, this view focuses on relationships between different agents, and knowledge interactions (Roeland, Hertog, 1998). Geographic concentration clearly favors innovation (technological but also organisational or commercial) through information exchanges or knowledge spillovers between close firms. By locating close to one another, businesses are able to acquire information, communicate and share inputs and benefit from a "collective" advantage that could not otherwise be achieved alone, while keeping their flexibility and autonomy. Note that in this context, the definition of the cluster is no more industry-based but rather on the strong inter-relationships among firms. The cluster agglomeration's coherence now stems from common goals, a shared vision of local development, and trust

sustained by repeated formal and informal cooperation between firms (Saxenion, 1994 ; Rosenfeld, 1997).

The competition and innovation mechanisms described in the two above literatures put strong objections to the popular view that geography no longer matters for business in the Digital Economy (Negroponte, 1995). In fact, since market globalization and the ease of transportation and communications allow firms to move their operations virtually anywhere, they now get free from the former natural or inputs constraints and can choose the best place for maximising clustering effects. Two questions then come up: first, is there evidence of regional concentration and clustering in IT industries? ; second, since, as we have seen, there are a wide range of local externalities, which theory best contribute to the understanding of observed clustering dynamics? The following table summarizes the different theories of agglomeration, and underlines in each case the key variable to consider to test their existence and magnitude in a particular geographical area.

Table 1. Theories of Agglomeration Externalities

References	Cluster Approach	Externalities and Cluster Dynamics	Key Variable
Marshall, 1890 ; Arrow, 1962 ; Romer, 1986 ; Henderson, 1986	Industry concentration in a geographical area	Saving on transport costs, labor market pooling, information spillovers within industry	Local Industry Specialization
Porter, 1990, 98	Vertical (buyer/supplier) and horizontal (shared resources, technology or market) links	<i>Ibid</i> + Competition	Ind. Special. + Competition
Jacobs 1969 ; Glaeser et al. 1992	Inter-industry links in a geo area (city)	Knowledge transmission between sectors	Industry variety
Krugman, 1991 ; Ciccone, Hall, 1996 ; Holmes, 1999	Spatial concentration and regional productivity differences	Local demand, variety of differentiated products	Scale of local economic activities
Saxenian, 1994 ; Rosenfeld, 1997	Active channels supporting commercial & information flows	Cooperation, Social interaction (trust, shared vision)	Interfirms linkages

To test the relative importance of each type of agglomeration externalities in the IT industries, we will use geographical data from the U.S. Census Bureau on industry employment across the 51 States. However, in implementing this study, a key issue concerns how to define the IT industries and to appropriately measure regional concentration. The next section deals with these problems.

3. The Data Set

Definition of IT industries

The choice of the set of industries making the IT sector upon which to base our study is not an easy task: governmental, professional and academic bodies use their own definition (SIC and NAICS statistical system, OECD, Department of Commerce, American Electronics Association, WTO...). The most common method (DoC, 1999) consists in an extensive view bringing together three categories labeled as hardware, software and services, communications (equipment and services): 'IT industries produce, process or transmit information goods and services as either intermediate demand (inputs to production to other industries) or as final products to consumption, investment, government purchases, or exports. Other industries were considered to be IT industries since they provide the necessary infrastructure (communications) or the Internet to operate' (in DoC, 1999, *The Emerging Digital Economy*, Appendices, p. A1-18). The *Internet Economy Indicators* of the University of Texas (1999) similarly follow a chain value-oriented classification, with three levels: infrastructure, application and intermediary & Internet commerce. A common feature of these classifications is that they include computer and electronic spare components production (such as semiconductors, electronic tubes or printed circuit boards which of course have many different uses outside the IT activities). However, as goods such as computers and hardware electronics are increasingly used in almost every industry or service sector of the economy, it is more and more difficult and debatable to draw accurate boundaries of these sectors. Moreover, the traditional distinction between infrastructure and applications is getting less and less valid in IT industries (for example, does an Internet Service Provider ISP belongs to the first or the latter category?). We have therefore chosen not to include hardware manufacturing in our definition and to strictly focus on activities producing final and self-sufficient services to business or individual customers. So, we do not consider computer manufacturing, but we include the numerous services related to the design, installation, maintenance, upgrading and repair of computer systems and networks.

Once the scope of IT activities selected, a second problem lies in the identification of the appropriate statistics to measure them. This task is complicated by the change in US statistical system implemented in 1998. The Standard Industrial Classification (SIC) system has been used to classify employment sectors by the type of activity in which they are engaged throughout the late 1900's. It is based on a four-digit industry coding system and groups industries by sectors such as Wholesale Trade, Services, and Manufacturing. Today, new driving industries like biotechnology, software, environmental technology, and communications do not fit into the classic SIC definitions of Manufacturing or Service sectors. Industries broadly labeled "biotech" or "online services" straddle sector definitions, refusing to fall neatly into the categories outlined by the SIC system. The US have launched in 1998 a new industry classification system called NAICS in order to better take into account the growing importance of the IT sectors. This in-depth revision of the economy statistical description aims at capturing new businesses, fast developing high-tech sectors and detailing the various activities confused in indiscriminate and obsolete industries groupings. Therefore the boundaries of

the former sectors and industries were redefined; the former SIC 4 and 5-digit classification reshuffled; new numeric codes introduced with detailed codes of maximum six digits. A new Information sector has been defined, bringing together 34 industries that produce, process and distribute information. This major statistical change translates the growing weight of these activities in the US economy. An interesting feature of the NAICS system is that hardware and software industries, which used to be traditionally mixed up within aggregated data, now belong to separate industry classifications. This fits nicely with our definition and our wish to take away hardware manufacturing from our calculations. We eventually distinguish six different IT industries: Cable, Telecommunications, On-line services, Software, Data processing and Computer systems design. Table 2 presents them, their statistical code and the corresponding scope of activities.

Table 2. Description of the IT Industries

Industry	NAICS classification	Activities
Telecommunications	5133 Telecommunications	Firms engaged in operating, maintaining or providing access to facilities for the transmission of voice, data, text, video: wired local and long distance carriers, wireless carriers, telecom resellers, satellite operators.
Cable	5132 Cable Networks and Program Distribution	Programming material production and broadcast through cable-systems or direct-to-home satellite systems. It comprises the distribution firms that market these programmes to consumers.
On-line Services	514191 Online Information Services (sub-sector of 5141 Information Services)	Providers of information services (except news) such as Internet Service Providers, on-line (search routines, browsers, electronic mail) or telephone-based (toll call) information services.
Software	5112 Software Publishers	Computer software design, development, publishing and distribution. Includes support operations such as documentation design, installation assistance or support to customers.
Data processing	5142 Data Process. Services	Electronic data processing services (processing and preparation of reports from customers data bases, automated entry data services...).
Computer services	5415 Computer Systems Design and Related Services	Customized software development (e.g. CAD). Design of computer systems integrating hardware, software and communication technologies. On-site management of clients' computer systems and data processing facilities. Disaster recovery services.

Note the first five industries all belong to the new introduced Information Sector (51), while the sixth one is classified in Professional, Scientific, and Technical Services. This subgroup of the vast Services sector brings together activities where human capital is the major input (hence a disparate list mixing lawyer, architecture, design, marketing, consulting, advertising...).

Construction of the Data Set

Our data set is constructed from the Geographical Industry Series of 1997 Economic Census, displaying data at the State level for up to the six-digit industries. It contains information on employment, number of establishments, payroll in 1992 and 1997 for the 6 IT industries in 51 states. State-industry wages are obtained by dividing annual payroll by the number of paid employees. Data on total State employment come from the U.S. Bureau of Labor Statistics (seasonally adjusted non-farm payroll in March of the selected year). When for confidentiality reasons, employment information is not disclosed, we use the midpoint of the range provided by the Census report. The scale used in employment statistics is rather detailed: 0-19, 20-49, 50-99, 100-249, 250-499, 500-999, 1000-2499, 2500-4999, 5000-9999, etc. When employment in the State-industry is reported to be e , meaning the true number is between 250 and 499, we used 375. The estimation uncertainty so remains limited, except when employment exceeds 5000.

IT Specialization Measures

Our measure of local specialization in a specific industry is classically the fraction of that industry's employment in the state, relative to its national share of US employment.

State s specialization in industry i is then $\sigma_{is} = \frac{e_{is}/e_s}{E_i/E}$, where e_{is} is industry i

employment in state s , e_s the employment in state s , E_i the national employment in industry i , and E the US total employment. This ratio measures how specialized is a state in a particular industry relative to what it would be if the employment in this industry was randomly scattered across the country.

We then introduce three variables to capture the State specialization in IT industries.

First, the *State IT Mean Specialization*, i.e. the average regional specialization in the six selected industries. In State s , $MS_s = \frac{1}{6} \sum_i \sigma_{is}$.

Second, the *IT Convergence Factor* measuring how close and homogeneous are the six IT industry specializations in that state. Base on an inverse standard deviation form,

$$CF_s = 1 / \sqrt{\frac{1}{6} \sum_i (\sigma_{is} - MS_s)^2}.$$

And third, the *State Adjusted IT Specialization* is the IT mean specialization weighted by the convergence factor $AS_s = MS_s \cdot C_s$.

4. IT Regional Specialization in the US: the 1997 Picture

Before discussing State specialization results, it is useful to start with a simple description of the data. Table 3 presents for each IT industry the total employment, the State employment mean and standard deviation, the largest State employer and its share of national industry employment (primacy), the share of the five and ten largest State employers, the Herfindhal index (sum over the 51 States of the squared state's share of industry employment), and finally, the Ellison-Glaeser index (an adjusted version of the previous parameter obtained by summing the squared deviations of state employment share in the

industry from its share of national total employment). To compare the economic size of these industries, we also report 1997 revenue.

Table 3. 1997 Data by IT Industry

1997 Data	Cable	Telecoms	Online Services	Software	Data Processing	Computer systems
Total US employment	174 580	1 012 220	50 280	266 380	263 600	764 660
State employment Mean	3 423	19 847	986	5 223	5 169	14 993
Standard deviation	4 057	24 149	1 842	11 560	6 249	20 283
Highest level	20 243 (CA)	116 253 (CA)	9 822 (CA)	77 277 (CA)	27 088 (TX)	101 494 (CA)
Average primacy	0,12	0,11	0,2	0,29	0,1	0,13
5 first States	38%	40%	56%	55%	40%	41%
10 first States	57%	59%	73%	70%	58%	64%
Herfindhal index	0,047	0,048	0,087	0,113	0,048	0,055
Concentration index	0,0036	0,0036	0,029	0,045	0,0077	0,0089
Revenue (billion \$)	45,4	260,5	8	61,7	30,8	109

The sum of employment in the six industries amounts to 2,5 millions, which is comparable to DoC (1999) estimations of 2,6 millions, and slightly lower than the 1,5 millions of the CREC, Univ. of Texas study, which only consider Internet activities. The panel shows that the IT industries, despite huge differences in revenue and total employment, exhibit a common high geographical concentration. In each case, 50% of industry employment is obtained in less than 12 states.

Table 3 also gives three widely expected results. First, two key industries - telecoms and computer systems - concentrate 70% of total IT employment. Second, California appears five times out of six as the largest State employer in the industry, amounting to between 10 and 30% of industry national employment. Finally, the most recent and fast-growing industries - Internet online services and software - exhibit a higher level of geographical concentration, than the four other industries, whose concentration measures are roughly similar.

Let's now present specialization results by state in the US in 1997. Table 4 lists the 16 States where the IT Mean Specialization is greater than one. It shows that a high average specialization can be achieved, either with a very strong (greater than 4 or 5) specialization in one or two industries such as in Virginia (with online services) or in Nebraska (with data processing), either with an homogeneous high specialization in the six industries such as in Colorado, Texas and New-York. The third column shows that, whereas the measure of average specialization only varies from 1 to 2.1, the convergence factor is much more contrasted ranging from 0.45 to 3.84 (an 8.5 ratio). The interest of this parameter comes exactly from the fact that it captures the differences above underlined and tells us where the average specialization result comes from. Virginia and Nebraska have precisely amongst the lower convergence factors (respectively 0.64 and 0.54), while Texas which only just passes the required

level of 1 for mean IT specialization, has an almost equal specialization in the six selected industries obtains a record 3.8 convergence measure.

Table 4. IT State Specialization in 1997

State	IT Mean Special.	Convergence Factor	Cable Special.	Telecoms Special.	On-line Services Special.	Software Special.	Data Processing Special.	Computer Systems Special.
Virginia	2,11	0,64	0,97	1,34	5,10	0,99	1,00	3,27
Massachusetts	1,99	0,89	1,18	1,03	2,14	4,38	1,54	1,68
Colorado	1,90	2,62	2,19	2,01	2,21	1,39	1,34	2,22
Delaware	1,88	0,45	6,72	1,10	0,38	0,41	2,04	0,67
California	1,45	1,53	1,09	1,08	1,83	2,72	0,73	1,24
Nebraska	1,44	0,54	0,92	0,88	0,33	0,30	5,53	0,66
Maryland	1,39	1,80	1,20	1,13	1,08	0,92	1,44	2,59
New Jersey	1,35	1,57	1,17	2,26	0,60	1,01	0,89	2,18
Connecticut	1,29	1,95	2,04	1,04	0,83	0,91	1,98	0,93
New York	1,23	2,36	1,48	1,16	1,93	0,64	1,32	0,83
Georgia	1,21	2,50	1,81	1,56	0,60	0,91	1,15	1,21
Utah	1,12	1,99	0,50	0,89	0,83	2,10	1,29	1,09
Washington	1,10	1,93	0,77	1,10	1,57	1,93	0,37	0,85
North Dakota	1,05	1,38	0,65	0,58	0,47	1,43	2,52	0,67
Dis. of Columbia	1,03	2,95	1,23	1,11	1,45	0,35	0,95	1,08
Texas	1,00	3,84	0,86	1,20	0,68	0,86	1,47	0,94

However, these figures only inform us about the intensity of IT activities in the different States. To get the right economic picture, one must take into account their absolute size and regional magnitude. We therefore include in the next table the total number of IT jobs in the State and the corresponding percentage of total regional employment. Note our measure of employment is the total civilian labor force, which not limited to industry employment but also includes government jobs. This is why the results are notably smaller than similar evaluations by the AEA (1999) or Atkinson, Court (1999). In this table, we eliminated three formerly selected States: Delaware for data uncertainties (four out of the six 1997 industry employment are actually estimated figures), North Dakota and the District of Columbia, because the total IT jobs is lower than 10 000 (which gives little significance to later growth and specialization calculations). To support the discussion, we also indicate the adjusted specialization (i.e. mean specialization weighted by the convergence factor), the State IT overall specialization (i.e. the measure of specialization obtained when adding up the six IT industries employment figures instead of taking the mean of the six specialization levels), and finally the employment growth in the six IT industries between 1992 and 1997, both in absolute value and in percentage.

Table 5. Description of IT Industries size and growth in the most specialized States

State	IT Mean Special.	IT Adjusted Special.	IT Jobs (1000s)	% of local employment	IT State Special	1992-97 Jobs Creation (1000s)	1992-97 Jobs Growth (%)
Virginia	2,11	1,35	127,0	4,0	1,90	35,9	39
Massachusetts	1,99	1,77	107,0	3,5	1,67	36,6	52
Colorado	1,90	4,96	79,5	4,1	1,96	37,4	89
California	1,45	2,21	345,8	2,7	1,28	94,2	37
Nebraska	1,44	0,78	21,7	2,6	1,23	4,9	29
Maryland	1,39	2,50	74,3	3,3	1,59	15,6	27
New Jersey	1,35	2,12	142,7	3,9	1,86	28,0	24
Connecticut	1,29	2,51	38,5	2,4	1,16	9,1	31
New York	1,23	2,90	176,9	2,2	1,06	45,8	35
Georgia	1,21	3,02	99,9	2,8	1,34	26,8	37
Utah	1,12	2,22	22,3	2,3	1,09	6,1	38
Washington	1,10	2,12	52,8	2,1	1,02	16,9	47
Texas	1,00	3,84	190,7	2,2	1,08	56,1	42

The panel emphasizes the impressive performance of Colorado over the period. It also points out the interest of the specific IT specialization index defined in section 3, instead of specialization ratio or labor intensity for a single aggregated IT sector. Clearly our procedure of using the mean specialization of the six IT industries rather than their overall weight, introduces a strong voluntary bias, since it gives after all equal importance to each IT industry despite huge differences in employment levels. This is however the best way to take seriously the convergence assumption, and to argue that, whatever strong specialization might be achieved in one industry, the decisive factor in fostering IT employment growth is the local and significant presence of all six of them. The convergence factor and the adjusted IT specialization afterwards attempt to give quantitative measures. The figures in table 5 provides in this context evidence in favor of this theory (consider for example Texas, California, and the differences between California and Colorado). This however merely suggests the existence of the convergence mechanism, which we should now spot and evaluate in a comprehensive and rigorous manner. This is the objective of the following section.

Before that, we conclude with a brief comment on two reports supporting the previous results. First, the need to take into account the convergence factor to get the right picture of a State IT specialization, is confirmed by data collected, on a quite different methodology, by the American Electronics Association (1999) on State jobs creation between 1990 and 1997. The results are summarized in table 6. Though AEA counts so-called high-tech jobs, the method allows useful comparison with our calculations. Actually, for measurement problems, AEA adopted a fairly conservative and restricted definition of high-tech industries, excluding biotechnology, engineering services, research and testing activities. This eventually leads us to three main categories: electronic and computer production, communication services, software and computer services. The two latter roughly corresponds to our definition of IT industries.

Table 6. AEA Estimation of State high-tech Employment Evolution 1990-97

State	Jobs	Jobs Growth	1998 Total	% of local	1998 exports	1990-98 Exports
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	creations	(%)	jobs	employ.	(billion \$)	growth (%)
Texas	101 700	37	375 933	5,4	41	173
California	66 100	9	784 151	6,9	64	113
Georgia	46 400	54	132 524	4,4	4	135
Colorado	40 000	44	131 854	8	4	100
Washington	35 900	59	97 025	4,7	3,3	135
Virginia	33 000	27	154 712	6	4	90
Illinois	25 800	14	207 201	4,2	16	92
Massachusetts	- 16 600	- 7	205 091	7,7	11,5	40
New York	- 30 200	- 9	320 410	4,9	15	38
Maryland	-	-	97 484	5,4	1,8	64

This table shows again the dynamism of States such as Texas, Georgia, who display just average level of State or mean IT specialization, but take profit of an homogeneous and balanced specialization in all IT key industries, as illustrated by their high convergence factor. But since the basis for jobs calculation is not identical, we cannot push further ahead the comparison with our results.

5. Dynamics of IT Specialization between 1992 and 1997

To evaluate the role of agglomeration externalities in IT industries' growth, we now consider one IT industry in a State and look at the growth rate of these regional industries as a function of the different agglomeration externalities discussed in section 2: localization, urbanization, convergence.

1992 Data Set

To do that, we first need to collect older data on IT industry state employment, to measure their recent growth. To get comparable data, we must not go too much further into the past, and decided to use 1992 Census results. However, because of the change in the classification system in 1998, this is not a straightforward task. We actually first have to map the IT industries defined in the new NAICS system with the former SIC classification, as explained in table 7.

Table 7. 1997 NAICS and 1992 SIC Data Compatibility by IT Industry

NAICS code	Business Description	SIC code	Business Description
5132	Cable Networks and Program Distribution	4841	Cable and other Pay Television Services
5133	Telecommunications	481	Telephone
		482	Telegraph communications
		489	Communications services
514191	On-line Services	7375	Information Retrieval Services

5112	Software Publishers	7372	Pre-packaged Software
5142	Data Processing Services	7374	Computer Processing and Data Preparation and Processing Services
5415	Computer Systems Design and Related Services	7371	Computer Programming Services
		7373	Computer Integrated Systems Design
		7379	Computer Related Services

Preliminary facts

We begin with a quick review of the most striking evolutions at the regional and industry level. Table 8 first presents the change observed in the size and intensity of State IT activities.

Table 8. Means and Standard Deviations of IT Industries Variables in 1992 and 1997*

Variable	Mean	Stand. Dev.
1997 State IT Jobs (000s)	49,64	63,45
1997 State IT Jobs (% total employ.)	1,79	0,86
1997 State IT Specialization	0,86	0,41
1997 IT Industries Mean Specialization	0,87	0,44
1997 Convergence Factor	3,23	1,89
1997 State IT Adjusted Specialization	2,38	1,32
1992 State IT Jobs (000s)	36,54	46,36
1992 State IT Jobs (% total employ.)	1,48	0,64
1992 State IT Specialization	0,86	0,37
1992 IT Industries Mean Specialization	0,82	0,40
1992 Convergence Factor	2,92	1,17
1992 State IT Adjusted Specialization	2,10	0,96

* For 50 States: Wyoming was not considered because the local total number of IT jobs is under 1200, i.e. three times smaller than the next state when ranked according to IT jobs.

This table shows an interesting empirical finding, confirming the convergence hypothesis and the design of the following econometric regression. On average, IT industries experienced an impressive growth over the period: State jobs increase by 36%. Meanwhile, standard index such as State overall IT specialization merely changes. But, if we consider the State IT Mean Specialization, we notice that, while the variable's mean remains fairly the same between 1992 and 1997, the standard deviation increases by 10%. The trend is more marked when we take into account the convergence factor: mean and standard deviation of the State adjusted specialization variable respectively grows by 13 and 37%. The growing heterogeneity and variance in IT industries average specialization at the State level is illustrated by the following figures.

Figure 2. 1997 IT Mean Specialization in the US

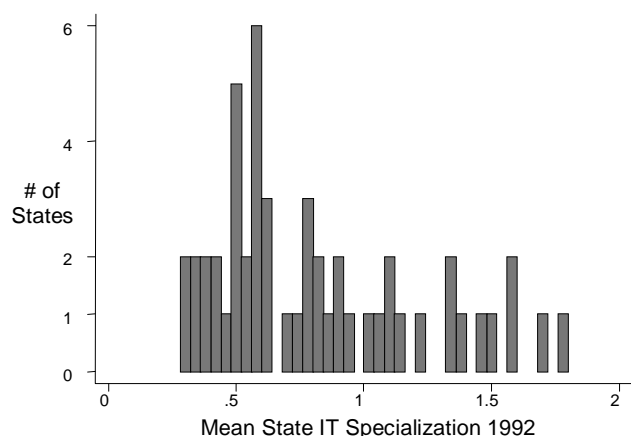


Figure 3. 1992 IT Mean Specialization in the US

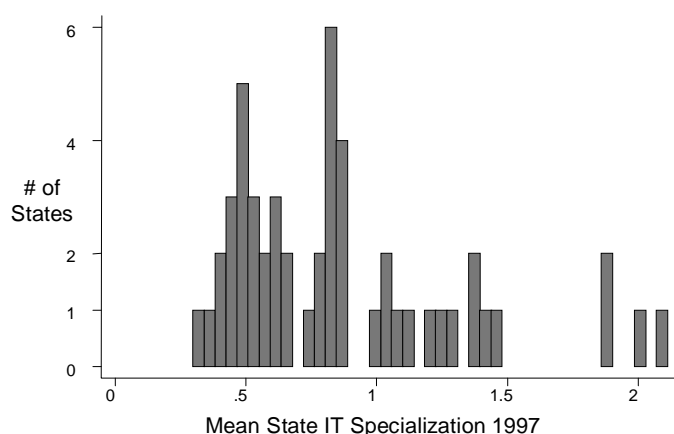


Table 9. 1992-97 Growth Patterns by IT Industry

1992-97 Growth	Cable	Telecoms	Online Services	Software	Data Processing	Computer systems
Employment change	45 327	69 122	18 385	135 353	33 882	366 509
Growth	35,1%	7,3%	57,8%	103,3%	14,8%	92,1%
Jobs Creation	46 357	94 390	24 701	137 249	52 837	367 103
Jobs Destruction (nb. States)	- 1030 (7)	- 25 268 (19)	- 6 316 (10)	- 1 896 (3)	- 18 955 (14)	- 594 (1)
Jobs 'churn' *	2%	27%	26%	1%	36%	0%
State Change Mean	1 216	3 764	1 272	6 132	2 455	9 427
Standard deviation	6 338	10 205	2 825	19 560	5 258	51 371
Largest jobs creation (	4 627 (GE)	18 786 (TX)	6 081 (VA)	40 748 (CA)	10 477 (NY)	47598 (CA)
Share of 5 and 10 first States in employ. change	41% / 65%	50% / 71%	66% / 82%	57% / 74%	52% / 68%	39% / 62%
First State growths (with jobs creation greater than 2000, 1000 for online services)	Colorado 260% Georgia 99% Illinois 56%	Utah 60% Colorado 52% Arizona 34%	Virginia 880% Colorado 372% Washington 359%	New Hamp. 240% Pennsylvania 195% Arizona 194%	New York 84% Nebraska 78% Connecticut 71%	Arkansas 484% Kentucky 232% Georgia 140%

* defined as the ratio between jobs creation and jobs destruction in the industry.

Table 9 shows how this massive growth of the IT industries drives considerable change in the geographical distribution of employment. Overall jobs creation in the industry actually hides considerable transfers between states, as the jobs destruction and 'churn' indicate. Besides, the relative value of the mean and standard deviation in IT state employment points out the enormous dispersion of growth records. A third interesting feature is that, though between 62 and 82% of employment change is carried out in only ten states, California is no more the permanent leader in jobs' creation either in percentage or, more surprisingly, in absolute term.

Growth Model

Based on Glaeser and al. (1992), we present a growth model's specification where the growth rate of the firm's technological ability has both national and local components, the latter depending on three agglomeration externalities: localization, urbanization (here considered measured by the size of local population, as a proxy for economic overall activity) and convergence (homogeneous local specialization in the six selected IT industries).

We consider a firm in industry i and the state s . Its production function has the form $A_t f(l_t)$, where A_t represents the level of technology and l_t labor input at time t . For each firm, technology, prices and wages w_t are given.

$\text{Max}\{A_t f(l_t) - w_t l_t\}$ leads to $w_t = A_t f'(l_t)$ (labor input set to equate marginal productivity to the wage).

Assume now that A_t has both notional and local components: $A_t = A_{national,t} \cdot A_{local,t}$ and set $f(l) = l^{1-\lambda}$ with $0 < \lambda < 1$.

The growth rate of industry employment in that state will then be:

$$\lambda \text{Log} \left(\frac{l_{t+1}}{l_t} \right) = \text{Log} \left(\frac{A_{t+1}}{A_t} \right) - \text{Log} \left(\frac{w_{t+1}}{w_t} \right)$$

Finally, we assume that local technology grows at a rate depending on the three different externalities in the industry and the geographical area:

$$\text{Log} \left(\frac{A_{local,t+1}}{A_{local,t}} \right) = S(\text{localization, urbanization, convergence, initialconditions}) + \varepsilon_{t+1}$$

The growth model is then defined in equation (1) as:

$$\begin{aligned} \lambda \text{Log} \left(\frac{l_{t+1}}{l_t} \right) = & \text{Log} \left(\frac{A_{national,t+1}}{A_{national,t}} \right) - \text{Log} \left(\frac{w_{t+1}}{w_t} \right) \\ & + S(\text{localization, urbanization, convergence, initialconditions}) + \varepsilon_{t+1} \end{aligned} \quad (1)$$

Econometric Results

We examine employment changes at the State-IT industry level between 1992 and 1997 using the regression specified in equation (1). The measure of localization is given by the industry specialization in the state, σ_{is} defined in section 3. To address the urbanization theory in its simplest form, we use the total employment in the state as a measure of local economic activity. Finally, we test two different measures of the convergence process: the State IT Mean and Adjusted Specialization. Table 10 describes the variables. The dependent variable is (log of) the ratio of employment in that industry and the state between 1992 and 1997. The mean of this variable is 0,41 (this corresponds to an 8,5% annual growth). The standard deviation of 0,47 again indicates the great dispersion of growth performance.

Table 10. Variables Means and Standard Deviations

Variable	Mean	Standard Deviation
Log(1997 Employment/1992 Employment) in State and IT Industry	0,411	0,467
Log(1997 U.S. Employment/1992 U.S. Employment) in the IT Industry	0,383	0,264
1992 Wages in the State and the IT industry (thousands of dollar / quarter)	8,648	2,339
1992 State-Industry Specialization	0,877	0,701
1992 State Average Specialization in the six IT Industries	0,889	0,440
1992 State IT Adjusted Specialization	2,302	1,043
1992 State Total Employment (in millions)	2,351	2,322

Table 11 presents our results of the regression of employment growth across state-IT industry, with 225 observations. Given definition problems, and the fact that in 1992 this activity merely existed, we actually did not consider the on-line services data. In addition to that, we also eliminated 25 other observations, corresponding to situations where one of the data either in 1992 or 1997 was estimated, or where the total number of jobs did not exceed 500 and would lead to unrealistic growth figures. We include as control in the regression the 1992 log of wage in the state-IT industry (to control the potential move of firms or workers to low wages states).

Table 11. State-IT Industry Growth between 1992 and 1997

Dependent Variable	Log(1997 Employment / 1992 Employment) in the State and the IT Industry				
	(1)	(2)	(3)	(4)	(5)
Constant	0.044 (0.19)	0.07 (0.19)	0.1 (0.19)	0.02 (0.19)	-0.06 (0.19)
Log(1997 national employment / 1992 national Employment) in the industry	1.12 (0.1)	1.10 (0.1)	1.15 (0.1)	1.15 (0.1)	1.09 (0.1)
State-Industry wage in 1992	-0.02 (0.1)	0.006 (0.1)	-0.08 (0.1)	-0.09 (0.1)	-0.007 (0.1)
State Employment in 1992	-0.04 (0.02)	..	..	..	-0.05 (0.03)
State-Industry Specialization in 1992	..	-0.1 (0.03)	..	..	-0.09 (0.03)
Mean State IT Spec. in 1992	..	..	0.06 (0.06)	..	..
IT Convergence Index in 1992	..	..	..	0.06 (0.02)	0.08 (0.02)
Adjusted R ²	0.397	0.413	0.393	0.410	0.438

Standard error in parentheses.

As in Glaeser and al. (1992), we find that initial wages are uncorrelated with employment growth, while the coefficient on national industry employment change is above one in the five models. The table shows that the effects of agglomeration

externalities we investigate are second-order magnitude behind national industry evolution.

The overall results on externalities support the convergence hypothesis, and object to localization and urbanization theories' predictions. Column 1 shows that the undifferentiated weight of economic activity, here measured by total state employment, hurts growth in the city-industry, but the effect is not statistically significant. The following column gives opposite results to the localization theory's prediction. The coefficient on the local specialization variable is actually negative and significant, though quantitatively small. If we raise the measure of state-industry specialization by one standard deviation, the cumulative growth of employment over the five years slows by 7 percent total, which is about one-seventh of a standard deviation.

On the contrary, the results of column 3 and 4 are consistent with the convergence hypothesis. We put aside the IT state mean specialization variable, which effect is not statistically significant, to focus on the adjusted IT specialization. Equation 4 shows that industries in states where the "convergence" of the six IT industries is more intense grow faster. The final column uses the three measures of externalities at the same time. The previous findings are confirmed, with similar signs and coefficient for the three explanatory variables. Local specialization and overall state size continue to exert a negative impact on growth of city-industry employment. On the contrary, local convergence between IT industries has a positive and significant influence. An increase of one and a half standard deviation in the adjusted IT specialization (1,56), as in Texas, actually raises growth of employment in the city-industry by 13% over the period (30% of a standard deviation).

6. Conclusions

We have shown in this paper that IT industry employment growth in a State is fostered by the co-location of close IT industries, whereas local specialization hurts. The interpretation proposed of this evidence is that the deregulation of the telecoms sector combined with the pace of innovations in IT support a process of convergence between formerly distinct industries such as Telecoms, Cable, Software, Internet services, Data Processing and Computer Design. Jacobs' diversity externalities - labeled as "convergence externalities" in this specific context - appears to be the most consistent with the evidence. This convergence mechanism also helps explaining the present geographical specialization patterns of the IT sector across the US. In particular, it accounts for the emergence of new clusters (in Colorado or Texas), amid the long-lasting well-documented clusters in Santa Clara, California (Silicon Valley) and the area around Boston-Cambridge Route 128 (Arthur, 1990 ; Saxenian, 1994).

This study could be extended in three ways. First of all, the econometric analysis of US data can be improved by adding complementary variables and using a smaller geographical unit. In this paper, the regional unit for analysis is actually the State. However, it is clear, as the Denver case illustrates, that a cluster is usually much smaller than a State. Since Glaeser and al. (1992) have shown that the magnitude of external effects increases as the geographical unit becomes smaller, we should expect better

econometric results by using data at the MSA (Metropolitan Area) level. The US Census Bureau has however not yet released these 1997 data. It would also be interesting to use other variables than employment to evaluate the local benefits generated by agglomeration externalities and measure industry growth: labor or total factor productivity, per-capita income. A second avenue for research consists in applying the same method to European countries to discuss the policy implications of the Digital Economy's fast growth on regional development and cohesion. Finally, the third direction consists in exploring and modeling the IO-foundations of the "convergence process" at the industry and firm levels. A possible solution to tackle this issue could be to examine equilibrium configurations models where the independence assumption between submarkets is relaxed and the bundling of technology different and hardly substitutable products allowed (Sutton, 1998).

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