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AGGLOMERATION ECONOMIES WITHIN IT-PRODUCING AND IT-CONSUMING INDUSTRIES IN U.S. REGIONS

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Abstract

This paper deals with the effects of the geographic concentration of economic activity on productivity through agglomeration economies in the U.S. economy. Our empirical study extends the literature on agglomeration economies in two directions. First we measure and compare the effects on productivity of geographic concentration in either information technology related activity (the IT sector) or in all other economic activities (the non-IT sector). Second we follow Jorgenson's (2002) reasoning regarding the significance of the differences between IT-*producing* sectors and IT-*using* sectors and assess the differential effects of concentration in IT-producing sectors and concentration in IT-using sectors on productivity. We utilize four measures of agglomeration and analyze effects at two levels of geographic disaggregation: U.S. states and U.S. counties. We perform the analysis using a model drawn from the growth accounting literature in which total labor productivity in a region is the dependent variable. It is modeled as a function of the region's capital-output ratio, the quality of the region's labor supply as measured by the level of education, and an agglomeration variable measured by concentration in the IT or non-IT sectors or in the IT-producing or IT-using sectors. The cross section estimates for a single year yield mixed results. We find weak evidence in favor of an effect of concentration of IT activity on productivity at the state level. We find stronger effects on productivity at the county level from concentration in IT-producing sectors.

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1. Introduction

There is a large literature that deals with the effects of IT[1] diffusion on productivity growth at firm, industry and national levels[2]. There is also a significant literature that addresses the implications of IT in other dimensions of the structure of economic activity such as the distance between agents, the geographical localization of industrial firms within nations or regions, the spatial networking of productive and knowledge activity, etc.[3] At the intersection of these two lines of research lies a topic of special interest for regional economic development policy: the effects on productivity growth of the spatial (geographic) distribution (concentration) of IT activities at the regional level. This relationship between productivity growth and IT activity can be analyzed through the lens of agglomeration or urbanization economies.

There are several motivations for studying the effects of IT on productivity through agglomeration economies. First, there is reason to believe that the development of IT has had an effect on the geographic concentration of economic activity. That the diffusion of information can now be done *from* any place *to* virtually any other place at a constant, low cost, through channels that are insensitive to spatial constraints (such as with internet, telephone, radio or optical transmissions through wires, cables, broadcast or satellite communications) is now an accepted feature of an advanced economy. This feature has led some to pronounce the "death of distance" in economic geography (Quah, 2001). And, if distance does not matter, then there will also be an end of agglomeration economies.[4] The theory of economic geography establishes that there are, on the one hand, *centripetal* forces, which lead to economic activity concentrating in space and, on the other hand, *centrifugal* forces pushing for the dispersing of economic activity[5]. The following are some examples of factors considered as centripetal forces in the theory of industrial organization: increasing

[1] In the literature the terms ICT (information and communications technology) and IT (information technology) have been used by various authors to refer to the same basic set of economic activities or sectors. In this paper we use the term IT to mean this same set of activities or sectors.

[2] See the recent survey from Draca et al. (2006).

[3] Many of these topics have been of particular interest to economic geographers.

[4] Quah (2001) argues that the development of the internet altered the balance between centripetal and centrifugal forces which govern the choice between agglomeration and dispersion of economic activities, especially for leading IT sectors. Indeed, as internet access grows, centripetal forces progressively fall, because the transportation costs of information are virtually zero. For instance, when the internet and telecommunication infrastructures improve, workers no longer have to be together in one physical collaborative communication. Hence, this argument predicts decreasing spatial agglomerations of economic activities. Preissl and Solimene (2003) claim that with IT diffusion, proximity and clustering are less necessary as well.

[5] Some authors have argued that the geography of innovation is now structured by the existence of professional communities in touch principally by internet. As a result, their physical spatial distribution is no longer important. See, for example, Foray (2004) and Torre (2006). However, Bettencourt et al. (2007) do not find empirical evidence supporting this contention.

returns to scale, pooling of skilled workers, availability of specific goods, and knowledge spillovers.

A second reason for studying the effects of IT on productivity through agglomeration economies is that many authors have stressed the increased importance of geographic proximity and regional agglomeration in the creation of new economic knowledge (Audretsch 2000) and for the promotion of innovation and growth (among others: Glaeser et al., 1992; Henderson et al., 1995).[6] Malecki (1987) was among the first to identify the significance of the geographic localization of high tech industry. He noted the efforts by economic development agencies in many communities and in all 50 U.S. states to reproduce the success of Silicon Valley and Route 128, whose very names are synonymous with the term "technological cluster." Being part of a large urban region, having abundant air transportation and having strong universities were also seen as constituting great advantages that could attract high tech firms[7].

In this paper, we test whether the concentration of IT-intensive activity is associated with agglomeration economies and, therefore, still subject to centripetal forces. Our analysis is based on the year 1990 for the United States.[8] We consider two sets of regional units of analysis: the 50 U.S. states[9] and the more than 3100 U.S. counties. We choose employment as our measure of industry size. Furthermore, in order to isolate the effects of IT activity concentration, we first split the economy into two sectors, following Porat (1977): IT and non-IT sectors, respectively.[10] Then, following a productive suggestion from Jorgenson (2001), we

[6] More recently Battersby (2006) has noted the effects of geographic isolation (the inverse of agglomeration) on U.S. and Australian productivity levels.
[7] However, Malecki (1987) argued that "encouraging and nurturing new companies bears more fruit than trying to lure firms from elsewhere. (…) the hope is that rapidly growing local high-tech firms might replace declining industries."
[8] Miribel and Le Bas (2005) provide reasons for using the data for 1990 in estimating regional productivity equations.
[9] While there are, in fact, only 50 states, the District of Colombia can be treated as either a state or a county in regional analysis. Thus there can be up to 51 observations in some of our state-level analysis.
[10] Jorgenson, Ho, and Siroh (2008) show the continuing utility of this IT non-IT distinction. Appendix Tables A1 and A2 provide lists of the 2-digit Standard Industrial Classification code industries in each category.

sub-divide the IT sector into two components: IT-producing and IT-using sectors.[11] The basis for this distinction is obvious: sectors such as finance produce no IT, but use a lot, and sectors such as computer manufacturing produce IT, but do not consume a lot. Basically our study proceeds by measuring the intensity, the density and the concentration of employment for a given sector (IT versus non-IT or IT-producing versus IT-using) and test whether these measures tend to influence productivity through agglomeration economies or diseconomies. The paper is organized as follows: In Section 2 we present our view of the state of the issue by surveying the literature on agglomeration economies and geographic concentration of activities within the IT paradigm. In Section 3 we develop the indexes for measuring agglomeration economies and the productivity equation that we use. In Section 4 we describe the data used to estimate the equations that provide tests of the hypothesis. In Section 5 we present our estimates and comment on the results. Finally, in Section 6, we conclude and offer some suggestions regarding future research programs in this area.

2. Agglomeration and the geographic concentration of activities within the IT paradigm

Because our concern in this paper is with agglomeration economies, we will first define them carefully. Then we survey the empirical literature dealing with agglomeration economies in general and in the particular context of IT. As noted by Rosenthal and Strange (2004) "*External* economies of scale exist when long run average cost falls in response to an increase in the size of a city or the size of an industry in a city". The main debate on agglomeration economies concerns whether they are related to the size of a city itself or to the concentration of an industry. The former effect is well known as an "urbanization economy" (Jacobs, 1969) which clearly is city-wide in scale and scope (associated with the city's diversity) and impacts productivity. The latter effect is known as a "localization economy," where it is the size of the industry concentration in the local area that impacts productivity.

[11] Appendix Table A3 provides a list of the 3-Digit SIC industries in each category.

This concept goes back to Alfred Marshall, who showed in 1920 that interactions between agents from the same industry within one territory ("the *industrial atmosphere*") tend to produce positive economies, which increase firms' productivity in the territory. Localization economies arise when a firm benefits from being near other *related firms in the same industry.*[12] There are at least three sources of localization economies: (1) the benefits of labor pooling, (2) the cost reductions for purchased inputs when economies of scale are realized in the industries that produce the purchased inputs, and (3) the better communication[13] and more rapid spreading of knowledge[14] or intra-industry knowledge spillovers.[15] In contrast, urbanization economies arise when firms are located in a large city, even if the firms do not belong to the same industry.

Many studies have emphasized the importance of geographical proximity in the production of new knowledge. Audretsch and Feldman (1995) have suggested that a tendency exists for high-technology industries to be geographically clustered, as if proximity to sources of knowledge spillovers was crucial for the firms to succeed in producing new knowledge through their Research and Development (R&D) activities. Agrawal et al. (2003), as well as others,[16] have significantly expanded on this basic evidence by showing that: (1) knowledge

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[12] A cluster is larger, it includes the Marshallian industrial district. For instance in Michael Porter's clusters, the firms work in different industries (see Bröker et al., 2003). According to Bogart (1998), external economies of scale or *externalities*, arise from the expansion in the size of the industry, even if the firm's size remains constant, and could be positive or negative.

[13] See Antonelli (2003).

[14] Some scholars (e.g., Acs 2002, Audrestch and Feldman, 1995, and Bottazi 2001) argue a direct relationship between the propensity for a given industry to concentrate geographically and its knowledge intensity. The geographic location may depend on the rate at which new ideas outdate old ideas. Industries that face rapid rates of knowledge obsolescence would benefit more by locating near sources of new knowledge so that they can easily access and evaluate new ideas. As expected, empirical work finds a high degree of spatial clustering for industries that face rapid knowledge depreciation and high technological opportunities. This typically describes industries at the earliest stages of their life-cycle, with a rapid pace of innovation. It appears that the IT sector is governed by rapid knowledge depreciation and strong technological opportunities. Hence the IT sector is more subject to geographical concentration. This clearly supports Porter's view that economies of agglomeration have "shifted in nature, becoming increasingly important at the cluster level, and not just within narrowly-defined industries" (Porter, 1998: 213).

[15] It is often noted that static economies of agglomeration are linked to cost minimization (economies of scale in production and distribution) due to proximity of inputs or proximity of markets in a context of specialized local division of labour while dynamic economies of agglomeration consist of advantages in knowledge improvements in learning.

[16] Acs (2002), Acs et al. (2002), Audrestch (2000), Saxenian (1994).

spillovers depend crucially on social ties between inventors, (2) proximity is essential for facilitating the communication that enables social ties to be built, and (3) these social ties endure after the individuals become separated. Their main conclusion is that "geographically proximity works to overcome social distance and, once relationships are established, individuals can remain close when they become geographically separated" (Agrawal et al., 2003: 20). In a more recent contribution Agrawal et al. (2007) point out that co-location of inventors facilitates access to knowledge, and clearly offers much greater benefits to individuals who are not otherwise socially connected. In another recent contribution following the lines of these previous studies, Bettencourt et al. (2007) find increasing returns in inventing activity (patenting) with respect to population size of metropolitan areas in the United States. In accord with predictions of both the new economic growth theory and the new economic geography, the analysis of Koski et al. (2002) show that there is a tendency for IT-related production and innovation to cluster geographically. They show that regional, county-level specialization of IT activities has increased in the 1990s.[17]

2.1 Quantitative analysis of agglomeration economies

Empirical studies of the effects of agglomeration on industries have found evidence of positive externalities arising from both urban and regional scales.[18] For example, Rosenthal and Strange (2003) show that for five of their six industries there is evidence of localization economies/agglomeration economies arising from spatial concentrations within the given industry. But they also find that these economies attenuate rapidly over the first few miles and then attenuate much more slowly thereafter. They emphasize that studies of agglomeration

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[17] For example, the well-known study conducted by Saxenian (1994) on the Silicon Valley and Route 128 in the United States shows that in these two areas economic activity is almost entirely dedicated to information and communication high-technologies.

[18] See also Caballero and Lyons (1990 and 1992); Bartelsman, Caballero, and Lyons (1994); Eberts and McMillen (1999); Paul and Siegel (1999), Rosehthal and Strange (2004), Tveteras and Battese (2006).

economies should be sensitive both to industrial organization and, especially, to the micro-geography of agglomeration.

Ciccone (2002) estimates agglomeration effects for France, Germany, Italy, Spain, and the UK. His estimates take into account the endogeneity of the spatial distribution of employment with spatial fix effects. The estimates suggest that in these European countries agglomeration effects are only slightly smaller than in the US: the estimated elasticity of (average) labor productivity with respect to employment density is 4.5 percent compared to 5 percent in the US (found by Ciccone and Hall, 1996). Ciccone concludes that

> "one of the questions requiring further research is the effect of agglomeration on industry structure. It seems reasonable to suspect that productivity gains in dense regions are partly realized through a change in industry structure. One of the reasons for this change in industry structure is probably that externalities are stronger in some industries that in others." Ciccone (2002)

Brülart and Mathis (2007) estimate agglomeration economies in European regions as well. They point out that one cannot exclude the possibility that permanent locational features favor both productivity and density. Their estimation technique enables them to deal with this simultaneity issue. The analysis of Ciccone is also improved since the sector definitions in Brülart and Mathis' data allow for disaggregated estimation. They confirm the presence of significant agglomeration effects at the aggregate level, with an estimated long-run elasticity of 13 percent, significantly higher than the one found by Ciccone (2002), and close to those found by Gambardella et al. (2002) on another sample of European regions. Brülart and Mathis find that these agglomeration effects have increased over time. They find especially strong, positive productivity effects from own-sector density in the financial services sector and also confirm Rosenthal and Strange's finding that there exists strong evidence that agglomeration economies operate at relatively small spatial scale.

Bode (2004) offers another point of view. Controlling more effectively for private returns that may be correlated with economic density, and broadening the scope of relevant externalities, he produces very different results: based on a data for German regions,[19] the productivity effects of economic density disappear when private returns are controlled for. However, he does find that other types of agglomeration externalities are relevant.

2.2 Quantitative analysis of IT

Pollard and Storper (1996) studied growth in three growth-generating sectors: industries handling information and advanced management functions ("intellectual capital"), high-technology industries ("innovation based") and "variety-based" industries, which are industries with high levels of product differentiation, relatively short production runs, and lower levels of mechanization than in mass-production industries. They focused on twelve metropolitan areas across the United States between 1977 and 1987. Their findings suggest that the determinants of regional employment growth in the 1980s might no longer be the relevant in the 1990s. "Variety-based" industries seemed to no longer be an engine of growth, but intellectual capital and innovation-based industries continued to exhibit high growth in all areas studied. Pollard and Storper were led to ask if it could be possible that the "variety-based" industries have a low propensity to agglomerate. They thought that one reason for these industries' low propensity to agglomerate could be the telecommunication revolution, which might have reduced the importance of localization economies.

Beardsell and Henderson (1999) examined the spatial evolution of the computer industry and its impact on productivity across 317 metropolitan areas in the USA from 1970 to 1992. First, they studied the evolution of employment to see if it concentrates in fewer locations or if patterns appear relatively fluid. They also emphasized the importance of locational characteristics (such as labor pooling) as determinants of the location behavior of computer firms. Finally, they found strong evidence of localization economies (own industry

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[19] The spatial units are German NUTS 3 regions.

externalities) as determinants of productivity growth, and little evidence of urbanization economies.

Graham and Kim (2007) use an empirical analytical framework for agglomeration economies based on a combination of a translog production function and an inverse input demand system. Estimation of their system of equations allows them to identify effects on total factor productivity (TFP), partial factor productivity, factor prices and factor demands. They use firm-level data for UK manufacturing and service industries. They find positive agglomeration elasticities for each of nine industry groups. For manufacturing industries they have an elasticity estimate of 0.024, for construction it is 0.141, and for IT it is only 0.066. Berghäll (2008) analyzes the Finnish IT sector. She notes that high (and increasing) scale elasticities relative to firm size are more related to firm and industry levels than to external economies of scale. She finds that agglomeration economies have weakened with industry life cycles.

Condliffe et Latham (2006) using a data set recently available containing US establishment births by county, present evidence that firms in the information technology industry respond positively to the economies found in metropolitan areas. This implies that the characteristics of such areas relative to those of non-metropolitan areas (population size, educational attainment of the labor force, and various kinds of agglomeration economies) make them attractive locations for information technology establishments. Miribel (2001) and Le Bas and Miribel (2005) find evidence that the so-called “death of distance” argument is not relevant for IT activity in the US economy. They divide all economic activity into information technology (IT)-related activity and all other activities. They estimate three empirical models of labor productivity using agglomeration as measured by IT and non-IT concentration, localization, and density to show that the geographic concentration of IT employment has a greater positive effect on labor productivity than the geographic concentration of all other activities. This confirms stronger agglomeration economies in the geographic areas where IT activity is more concentrated. A limitation of their study is in their hypotheses regarding all IT and all non-IT sectors. We adopt the same lines of reasoning and the same empirical models but we disaggregate all IT activity into two basic groups of activities, namely, IT-producing and IT-consuming industries.

3. Measuring agglomeration economies in a labor productivity framework

This section describes the methodology we use to measure agglomeration economies based on the spatial clustering of economic activity within a labor productivity framework .

3.1 Measures of agglomeration

Our measures are based on a variety of employment magnitudes. Four different types of measures are used to evaluate the externality effects of employment clustering: (1) a density index, (2) an intensity index, (3) a concentration index, and (4) a location quotient. The first two and the fourth aim to assess the effects of agglomeration of economic activities at the county level while the third applies only to the state level.

We denote by L_{ijk} the total employment in sector i of county j in state k. $L_{\cdot jk}$ is the total employment of county j in state k, a_{jk} is the area of county j in state k, and a_k is the area of the state k. In our study i stands for 4 sets of industrial sectors: IT, non-IT, IT producing and IT-using (but recall that IT-producing and IT-using sectors are components of the aggregate IT sector).

1. Our intensity index is the simplest measure; it is defined as

   $$I_{ijk} = L_{ijk} / L_{jk} \qquad (1)$$

   It measures the relative importance of sector i in a county as the share of total employment.

2. Our density index is also quite simple; it is defined as

   $D_{ijk} = L_{ijk} / a_{jk}$ (2)

   It measures the density of sector i in a county.

3. Our concentration index is somewhat more complex. States differ not only in their physical sizes ($a_{.k}$) and their total numbers of employees ($\Sigma_j L_{jk}$) but they also differ in their spatial distributions of population and workers. Our concentration index tries to capture this dimension. The concentration index is the ratio of the sum of county employment densities, weighted by their share of state's employment, and state overall density. For a given state, k, and a sector i, the concentration index ($CONC_{ik}$) is given by:

$$CONC_{ik} = (\Sigma_j \; L_{ijk}/ a_{jk} \, . \, L_{ijk} / \Sigma_j \; L_{ijk})/ (\Sigma_j \; L_{ijk} / \Sigma_j \; a_{jk}) \qquad (3)$$

   A value of 1 for the concentration index will indicate an even distribution of employment across counties in state k. The higher the value, the more employment is concentrated into few counties. The maximum value depends on the physical sizes of the counties in state k. Although this measure is not perfect, it has the merit of expressing at the state level what is happening across counties within each state. For each sector we have a concentration index. However, since we are interested in the *relative* effect of IT-using and IT- producing employment concentration on state productivity, we will consider as well the ratio of those two employment concentration measures[20].

4. Location quotients

[20] This will also have the advantage of avoiding multicollinearity between the two concentration ratios.

Our approach uses counties' production functions to relate county labor productivity to employment location. We estimate the relative effect of the location of IT-using and IT-producing activities on county productivity using location quotient measure of county differences in industrial mixes. Although the location quotient measure is usually used when many different industries are considered, the technique is still applicable when only two types of "industries" are considered, namely the IT-using and IT- producing industries.

The location quotient for sector i of county j in state k is defined as:

$$LOC_{ijk} = (EMP_{ijk} / EMP_{.jk}) / (EMP_{i.k} / EMP_{..k}) \quad (4)$$

Where the "." Is used to indicate summation over the relevant subscript. For each county, location quotients are computed for each type of employment, IT-using and IT- producing. A high value of the location quotient for one type of industry in a given county indicates that activity in that industry is more intense in that county compared to the overall state intensity in that industry. This measure is conceptually related to the concentration ratio previously defined, but does not take the physical *sizes of counties* into account and is computed for each type of industry in each county. The aim is to compare the *relative* effect of IT-using concentration compared to IT-producing concentration on productivity. Hence, we will also use the ratio of the two location quotients to evaluate the effect of one compared to the other. This model assumes that differences in states' labor productivities can be explained in part by differences in the localization patterns of IT activity across states.

3.2 The labor productivity equation and main variables

In order to test for the presence of agglomeration economies we use a normal Cobb-Douglas production function converted into a labor productivity equation to which we add a variable taking into account the stock of human capital at the county level, $EDUCATION_{jk}$, and one of the measures of agglomeration described above, C_{ijk}.[21] Our Basic equation then is

[21] The methodology has been previously used by Graham (2000) and Le Bas and Miribel (2005).

$$\ln(\text{PRODUCTIVITY}_{ijk}) = \ln(A_{ijk}) + \alpha_1.\ln(\text{CAPITAL/LABOR}_{ijk}) + \beta_1.\ln(\text{EDUCATION}_{jk}) + \gamma_1.(C_{ijk}) \quad (5)$$

where $\text{PRODUCTIVITY}_{ijk}$ is a measure of labor productivity (output per worker) in sector i of county j of state k, which depends on total factor productivity ($\ln A_{ijk}$); $\text{CAPITAL/LABOR}_{ijk}$ is the capital to labor ratio, EDUCATION_{jk} is the percentage of the county labor force with a high school education or better; and C_{ijk} is one of the measures of agglomeration for sector i of county j in state k, *i.e.*, $C_{ijk} \in \{I_{ijk}, D_{ijk}, CONC_{ik}, LOC_{ijk}\}$.This productivity equation can be thought of as having been derived from three complementary theories: (1) the growth accounting model (see Barro and Sala-I-Martin, 2003), (2) Lucas' theory of the importance of human capital (Lucas, 1988), and (3) Graham's (2000) pioneering theory of the role of the concentration of economic activity. In all cases we hypothesize that $C_{ijk} > 0$, that is, agglomerations have the effect of increasing productivity. This is as opposed to the effect of congestion, which may decrease productivity.

4. Data

The variables for our analysis had to be obtained at both the state and county levels because we estimate two sets of models, one using the 50 U.S. states and the District of Columbia and the other using the 3141 U.S. county equivalents for the year 1990. The variables needed to estimate all models are output, capital, employment, education and land area (see Appendix Table 1 for a list of variables used and their summary statistics). We use the same procedures to estimate output and capital stocks at the county level as Le Bas and Miribel (2005). Other county information such as area (in square miles), population, and education levels, were obtained from the decennial census of population from the U.S. Bureau of the Census. The education variable is defined at the at both the county and state levels as the percentage of the population that has graduated from high school, but not from college.

5. Estimation and results

The data described in the preceding section were used to estimate the parameters of a series of models based on Equation 5. The individual models use alternative levels of geographic disaggregation (states or counties), different measures of IT agglomeration (concentration, intensity, density and location quotients) and different disaggregations of IT itself (IT or IT-using and IT-producing). In Tables 1, 2 and 3 we report the results of estimating 19 models. We use OLS for all the estimates. Each of the models also uses White's heteroscedasticity consistent variances in computing the exact significance levels (p-values) of the parameters. We focus our attention here principally on the signs and the significance of the coefficients related to the four different proxies for agglomeration economies and not on their magnitudes. The values of the coefficients associated with the other variables (the capital/labor ratio and education) are similar to those found by Le Bas and Miribel (2005).

Insert Table 1 about here

Table 1 shows that, at the county level, we find considerable support for the positive effects of concentration on total productivity of both IT activities in general, and of IT-producing and IT-consuming activities separately. In particular the results for the IT intensity measures (columns (1) – (3)) confirm the hypothesis that IT-using activities are the source of agglomerations economies in the IT sector. However, we find that the coefficients related to the density of IT activities (columns (5), (6) and (7) are positive and highly significant, and ***larger*** for IT-producing activities (column (6)). The latter result would reject the hypothesis that IT-using activities are the source of agglomerations economies in the IT sector. Thus, in the end we do not have strong evidence regarding the source of productivity effects at the county level. The ratio of IT-using to IT-producing provides little explanatory power at the county level for the intensity measures.

Insert Table 2 about here

Table 2 shows that, at the state level, the effects of IT concentration on productivity are not evident except when IT-producing and IT-using sectors are separated and, even then, the effect is only evident when the ratio of the concentration measures for the two is used (column (6)). We interpret this result to mean that the effects of agglomerations on productivity at the level of states are unlikely to be strong enough to be detected. The fact that the ratio measure is significant indicates the importance of separating IT-producing from IT-using sectors. The negative sign of the ratio implies that relatively lower IT-using concentrations lead to higher productivity or that a higher concentration in IT-using activities may result in lower productivity.

Insert Table 3 about here

Table 3 shows the result of estimating the county level models using the location quotient measures. The results indicate that a higher concentration of a county's IT relative activity to the US average (column (2)) is even more productive than a high concentration relative to the state in which it lies (column (1)). This result indicates that there are additional state level productivity effects not accounted for by the fixed effects dummy variables included in the equations. The results can be interpreted as showing that when a county is more intensely concentrated in IT than its state, it exhibits larger agglomeration economies

The models give some support to the notion that the main source of agglomeration is IT-using rather than IT producing activity because the coefficients are slightly larger for IT-using for both the comparison with the state (.019 > .026) and with the national averages (.030 > .028).[22] However, each sector has a positive impact on county productivity. The data do not allow us to determine whether the effects are actually through IT capital or not.

6. Conclusions

We have calculated different indicators for measuring the effects of intensity, density, concentration and the localization of IT activities for the U.S. states and counties. For each indicator we use different specifications. Our cross section estimates for a single year yield mixed results. We find weak evidence in favor of an effect of concentration of IT activity on productivity at the state level. We find stronger effects on productivity at the county level from concentration in *IT-producing sectors.* These findings provide support for a well-known contention regarding the definition of agglomeration economies: the relative small size, or scale, of a county matches much more closely the Marshallian view of the positive effects of the geographic concentration of economic activity in industrial districts. The results reported in this paper make it clear that understanding the role of IT in the determination of regional productivity is important in the formation of regional development policies. The results also make clear that the seemingly self-evident utility of disaggregating IT into IT-using and IT-producing sectors may be more elusive to capture than one might have expected. Our results as a whole indicate that much work remains to be done on this topic. Our results are derived from a single cross-section analysis; much will be learned from the examination of the evolution of the effects of agglomerations of IT over time. The spillovers between IT sectors and non-IT sectors, and between IT-using and IT-consuming sectors also remain unexplored. Another potentially fruitful direction in which the research reported here might be extended is to utilize metropolitan areas instead of counties as the lowest level of geographic aggregation. Ciccone, (2002) suggested this and recent papers such as Kurre and Miseta (2008) have begun to explore this dimension more fully.

Finally, our analysis has implicitly assumed that the direction of causality is from IT agglomeration to productivity. If, in fact, causality is partially in the other direction (with

[22] Because the sample sizes are so large, these seemingly small differences in coefficient magnitudes are actually statistically significant.

productivity inducing agglomeration) then there is an endogeneity problem to be dealt with. Time series studies will be particularly useful in this regard.

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Insert Appendix Table A1-A4 here

Table 1. Estimates of the Productivity of Agglomerations of IT Measured as Concentration for U.S. States

Dependent Variable STATE PRODUCTIVITY (log)						
Independent Variables	(1)	(2)	(3)	(4)	(5)	(6)
C	4.738	4.88	4.78	4.86	4.85	5.11
***p*-value**	*.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
CAPTIAL/LABOR RATIO (log)	.434	0.427	0.432	0.428	0.428	0.463
***p*-value**	*000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
EDUCATION (log)	.309	0.294	0.305	0.294	0.298	0.220
***p*-value**	*.022*	*0.003*	*0.022*	*0.025*	*0.024*	*0.079*
IT CONCENTRATION MEASURES						
NON-IT	.425					
***p*-value**	.694					
ALL IT		0.520				
***p*-value**		*0.214*				
IT-PRODUCING			.296			
***p*-value**			*0.464*			
IT-USING				0.374		
***p*-value**				*0.154*		
IT-PRODUCING + IT-USING					0.187	
***p*-value**					*0.250*	
IT-USING / IT-PRODUCING						-.328
***p*-value**						*0.005*
R^2	0.722	0.730	0.724	0.733	0.854	0.765
Number of observations	50	50	50	50	50	50
***p*-value for H_0: F = 0**	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*

Note: White's heteroscedasticity consistent variances are used in the computation of the p-values.

Table 2. Estimates of the Productivity of the Intensity and Density of Agglomerations of IT for U.S. Counties

Dependent Variable COUNTY PRODUCTIVITY (log)							
Independent Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
C	6.252	6.333	6.330	6.277	6.277	6.279	6.276
p-value	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
COUNTY CAPTIAL/LABOR RATIO (log)	0.379	0.369	0.368	0.366	0.365	0.365	0.365
p-value	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
COUNTY EDUCATION (log)	0.106	0.134	0.136	0.161	0.161	0.161	0.162
p-value	*0.000*	*0.009*	*0.003*	*0.009*	*0.000*	*0.000*	*0.000*
COUNTY LEVEL IT MEASURES							
IT ITENSITY MEASURES							
IT Employment/Total Employment	0.202						
p-value	*0.000*						
IT-Producing Emp./Total Emp.		0.117					
p-value		*0.000*					
IT-Using Emp./Total Emp.			0.119				
p-value			*0.000*				
IT-Using Emp. / IT-Producing Emp.				-0.008			
p-value				*0.122*			
IT DENSITY MEASURES							
IT Employment/Area					0.007		
p-value					*0.000*		
IT-Producing Employment/Area						0.019	
p-value						*0.000*	
IT-Using Employment/Area							0.012
p-value							*0.000*
R^2	0.810	0.801	0.801	0.800	0.801	0.801	0.801
Number of observations	3005	3005	3005	3000	3005	3005	3005
p-value for H_0: F = 0	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*

Table 3. Estimates of the Productivity of Agglomerations of IT, as Measured by Location Quotients, in U.S. Counties

Dependent Variable COUNTY PRODUCTIVITY (log)						
Independent Variables	(1)	(2)	(3)	(4)	(5)	(6)
C	6.284	6.252	6.342	6.343	6.331	6.334
p-value	*.000*	*.000*	*.000*	*.000*	*.000*	*.000*
COUNTY CAPTIAL/LABOR RATIO (log)	0.378	0.379	0.368	0.369	0.368	0.369
p-value	*.000*	*.000*	*.000*	*.000*	*.000*	*.000*
COUNTY EDUCATION (log)	0.106	0.106	0.134	0.133	0.136	0.134
p-value	*.000*	*.000*	*.000*	*.000*	*.000*	*.000*
(COUNTY_IT-EMP/COUNTY_EMP)/(STATE_IT-EMP/STATE_EMP)	0.105					
p-value	*.000*					
(COUNTY_IT-EMP/COUNTY_EMP)/(US_IT-EMP/US_EMP)		0.114				
p-value		*.000*				
(COUNTY_ITU-EMP/COUNTY_EMP)/(STATE_ITU-EMP/STATE_EMP)			0.029			
p-value			*.000*			
(COUNTY_ITP-EMP/COUNTY_EMP)/(STATE_ITP-EMP/STATE_EMP)				0.026		
p-value				*.000*		
(COUNTY_ITU-EMP/COUNTY_EMP)/(US_ITU-EMP/US_EMP)					0.030	
p-value					*.000*	
(COUNTY_ITP-EMP/COUNTY_EMP)/(US_ITP-EMP/US_EMP)						0.028
p-value						*.000*
R^2	0.810	0.810	0.801	0.801	0.801	0.801
Number of observations	3105	3105	3105	3105	3105	3105
p-value for H_0: F = 0.00	0.00	0.00	0.00	0.00	0.00	0.00

Notes: Each equation is estimated using a full set of fixed effects dummy variables for the individual states. White's heteroscedasticity consistent variances are used in the computation of the p-values. ITU = IT-Using, ITP=IT-Producing, EMP = Employment.

Appendix Table A1. U.S. Information Technology Industries by Two-Digit SIC

SIC codes	IT INDUSTRIES
50	Wholesale trade
48	Communications
60 + 61	Banking
62	Security brokers
63	Insurance carriers
64	Insurance agents
67	Holding and investment
72	Personal services
73 + 83 + 86 + 87	Business and Other Services
78	Motion pictures
80	Health services
81	Legal services
35	Industrial machinery
36 + 38	Electronic, instrument and related equipment
37	Transportation equipment
27	Printing & publishing
28	Chemicals
41	Local & interurban passenger transit
45	Transportation by air
47	Transportation services
82	Educational services
--99	Administrative and Auxiliary of all industries

Source: U.S. Department of Commerce, Bureau of Economic Analysis

Appendix Table A2. U.S. Non-Information Technology Industries by Two-Digit SIC

SIC code	Non-IT or "traditional" INDUSTRIES
15	Construction
52	Retail trade
10	Metal mining
12	Coal mining
13	Oil & gas
14	Nonmetalic minerals
49	Electric, gas, & sanitary
65	Real estate
70	Hotels & lodging
75	Auto repair & parking
76	Misc. repair services
79	Amusement and recreation
24	Lumber & wood
25	Furniture and fixtures
32	Stone, clay, glass
33	Primary metals
34	Fabricated metals
20	Food & kindred products
21	Tobacco products
22	Textile mill products
23	Apparel & textile
26	Paper products
29	Petroleum products
30	Rubber & plastics
31	Leather products
42	Trucking and warehousing
39	Misc. manufacturing
44	Water transportation
46	Pipelines, ex. nat. gas

Source: U.S. Department of Commerce, Bureau of Economic Analysis

Appendix Table A2. U.S. Non-Information Technology Industries by Two-Digit SIC

SIC code	Non-IT or "traditional" INDUSTRIES
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65	Real estate
70	Hotels & lodging
75	Auto repair & parking
76	Misc. repair services
79	Amusement and recreation
24	Lumber & wood
25	Furniture and fixtures
32	Stone, clay, glass
33	Primary metals
34	Fabricated metals
20	Food & kindred products
21	Tobacco products
22	Textile mill products
23	Apparel & textile
26	Paper products
29	Petroleum products
30	Rubber & plastics
31	Leather products
42	Trucking and warehousing
39	Misc. manufacturing
44	Water transportation
46	Pipelines, ex. nat. gas

Source: U.S. Department of Commerce, Bureau of Economic Analysis

Appendix Table A3. 3-Digit SIC Information Technology Using and Producing Industries

High Technology Using Industries

SIC	Major Industry Group	3-Digit SIC Industry Name
281	Manufacturing	Industrial Inorganic Chemicals
282	Manufacturing	Plastics Materials and Synthetics
283	Manufacturing	Drugs
286	Manufacturing	Industrial Organic Chemicals
287	Manufacturing	Agricultural Chemicals
351	Manufacturing	Engines and Turbines (Industrial Machinery and Equipment)
361	Manufacturing	Electric Distribution Equipment
362	Manufacturing	Electrical Industrial Apparatus
369	Manufacturing	Misc. Electrical Equipment and Supplies
372	Manufacturing	Aircraft and Parts376 Guided Missiles, Space Vehicles, Parts
381	Manufacturing	Search and Navigation Equipment
382	Manufacturing	Measuring and Controlling Devices
384	Manufacturing	Medical Instruments and Supplies
386	Manufacturing	Photographic Equipment and Supplies
491	Manufacturing	Electric Services
493	Manufacturing	Combination Utility Services
506	Wholesale Trade	Electrical Goods
601	Finance, Insurance, and Real Estate	Central Reserve Depository Functions Closely Related To Banking
609	Finance, Insurance, and Real Estate	Banking
628	Finance, Insurance, and Real Estate	Security And Commodity Services
631	Finance, Insurance, and Real Estate	Life Insurance
632	Finance, Insurance, and Real Estate	Medical Service and Health Insurance
731	Business Services	Advertising
781	Business Services	Motion Picture Production and Services
871	Business Services	Engineering and Architectural Services
873	Business Services	Research and Testing Services
874	Business Services	Management and Public Relations

High Technology Producing Industries

SIC	Major Industry Group	3-Digit SIC Industry Name
357	Manufacturing	Computer and Office Equipment
365	Manufacturing	Household Audio and Video Equipment
366	Manufacturing	Communications Equipment
367	Manufacturing	Electronic Components and Accessories
382	Manufacturing	Measuring and Controlling Devices
481	Communications	Telephone Communications
482	Communications	Telegraph and Other Communications
483	Communications	Radio and Television Broadcasting
484	Communications	Cable and Other Pay TV Services
489	Communications	Communication Services, N.E.C.
504	Wholesale Trade	Professional and Commercial Equipment

573	Retail Trade	Radio, Television and Computer Stores
737	Business Services	Computer and Data Processing Services

Source: U.S. Department of Commerce, Bureau of Economic Analysis

Appendix Table A4. Summary Statistics for Variables in Regressions

	State Data		County Data	
	Mean	Standard Deviation	Mean	Standard Deviation
Employment (persons)				
Total	1,811,907	2,018,847	29,020	116,257
Non-IT	783,648	810,098	12,536	41,437
IT	1,028,260	1,224,950	16,512	76,215
IT-Producing	437,559	554,163	7,001	34,163
IT-Using	451,409	582,689	7,222	38,854
Output ($US billions)				
Total	101.00	129.00	1.62	7.43
Non-IT	49.60	61.30	0.80	3.31
IT	51.40	68.30	0.83	4.17
Capital ($US billions)				
Total	117.00	143.00	1.87	7.96
Non-IT	72.40	87.30	1.16	4.56
IT	44.50	57.20	0.71	3.50
Education (≥ high school)				
Labor Force, %	72.29	7.11	69.62	10.38
Area (thousands of square miles)	70.73	85.81	1.42	2.04
Number of observations	50		3141	