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KNOWLEDGE SPILLOVERS AND THE NEW ECONOMY OF CITIES

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September 2001

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ABSTRACT

Knowledge Spillovers and the New Economy of Cities

Despite much theorizing about the role of geographic concentration of employment in knowledge spillovers, local densities' role in promoting innovations has largely been unexamined. More often, studies have considered the effects of city size variables on innovative activity, although the role of scale was not the main focus of these studies. This paper considers the role of knowledge spillovers on innovations at the MSA level. We use patents per capita in an MSA as our measure of innovations in that MSA. We find that the rate of patenting is positively related to the employment density of the highly urbanized portion of an MSA (its urbanized area). Specifically, we find, on average, that rate of patenting is 20 percent to 30 percent greater in an MSA with a local economy that is twice as dense as the local economy of another MSA. Since local employment density doubles more than four times in the sample, the implied gains in patents per capita due to urban density are substantial. Thus, these findings confirm the widely held view that the nation's densest locations play an important role in creating the flow of ideas that generates innovation and growth.

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INTRODUCTION

An important finding from observing the geographic location of patent originations is that patenting is largely a metropolitan phenomenon. During the 1990s, 92 percent of all patents were granted to residents of metropolitan areas, although these areas account for only about three-quarters of the U.S. population, and for about 20 percent of land area of the continental United States. Historical data also show that patent activity is concentrated in cities. Pred (1966) examined U.S patent data for the mid-nineteenth century and found that patent activity in the 35 principal cities at that time was four times greater than the national average. Higgs (1971) found that the number of patents issued in the U.S. during the period 1870-1920 was positively related to the level of urbanization. Recent research recognizes an important link between national economic growth and the concentration of people and firms in cities. The high spatial concentration of people and firms in cities provides an environment in which ideas move quickly from person to person and from firm to firm. Dense locations, such as cities, are efficient producers of new ideas, leading to innovation and growth. But, as Jaffe, Trajtenberg, and Henderson (1993) find, the ability of people to receive ideas or their distance from the source of the ideas influences knowledge; the communication of ideas is relatively harder over longer distances. Thus, the high spatial concentration of people and firms in cities facilitates the exchange of ideas that underlies the creation of new goods and new ways of producing existing goods.

Surprisingly, local densities' role in promoting innovations has largely been unexamined. More often, studies have considered the effects of city size variables on innovative activity, although the role of scale was not the main focus of these studies. For example, Feldman and Audretsch (1999) find that the level of city employment is positively related to innovations in metropolitan statistical areas (MSAs). The papers by Ciccone and Hall (1996) and Sedgely and Elmslie (2001) are two exceptions. These authors examine the effects of density on rate of innovation at the state level (Sedgely and Elmslie) and on state productivity (Ciccone and Hall).

The purpose of this paper is to consider the role of knowledge spillovers on innovations at the MSA level. We believe that knowledge spillovers are positively related to the local employment density. We use patents per capita in an MSA as our measure of innovations in that MSA. We find that the rate of patenting is positively related to the employment density of the highly urbanized portion of an MSA (its urbanized area). We take this finding as evidence that highly localized knowledge spillovers are important for innovation and growth.

LITERATURE REVIEW

Endogenous growth models (e.g., Romer (1986) and Lucas (1988)) suggest that, among other things, innovation and growth depend on knowledge spillovers among agents or firms. As Glaeser (1996) has pointed out, the idea that "growth hinges on the movement of ideas, naturally led to a re-exploration of the economic role of cities in furthering intellectual flows." The notion that cities may enhance knowledge spillovers and economic growth goes back, at least, to Marshall (1890). When describing the benefits of dense concentrations of jobs in cities Marshall noted that "the mysteries of trade become no mysteries; but are as it were in the air." Krugman (1991) noted the difficulty with measuring knowledge spillovers is that "knowledge flows are invisible, they leave no paper trail by which they may be measured and tracked." Jaffe, Trajtenberg, and Henderson (1993) point out “knowledge flows do sometimes leave a paper trail” in the form of patented inventions. They looked at the propensity of new patents to cited patents that had originated from the same location. They found that a new patent is 5 to 10 times more likely to cite patents from the same metropolitan area than one would expect based only on the pre-existing concentration of R&D activity. They found that location-specific information spreads out slowly, making geographic access to that knowledge important to firms. They took these finding as evidence of knowledge spillovers in metropolitan areas.

While the literature suggests that knowledge spillovers should be enhanced in denser locations, little research has looked at density’s role in promoting local innovations. Ciccone and Hall (1996) found that county employment densities are important in accounting for differences in productivity levels across states. Sedgely and Elmslie (2001) look at patents per capita at the state level during the period 1970-95. They found that patenting at the state level is positively related to state population density. One problem with the Sedgely and Elmslie study is that the vast majority of the land area of most states is engaged in low-density rural activities, while its population is more highly concentrated in the state’s urban areas. Since knowledge spillovers have been associated with high-density urban activities, measures of density using the entire area of a state will understate urban density.

Following Glaeser, et al. (1992), much of the empirical research has focused on the effects of an economy’s industrial structure on innovation and growth. Two types of externalities thought to be important for innovation and growth have been identified in the literature. One type, referred to as MAR (Marshall-Arrow-Romer) spillovers by

Glaeser et al. (1992), argue that the exchange of ideas is enhanced in local economies that are highly specialized in one or two activities, such as the concentration of the semiconductor industry in the Silicon Valley. Jacobs (1969), however, discounts the importance of MAR type externalities that work within industries and argues instead that more industrially diverse local economies, such as New York City, are more conducive to the exchange of ideas.[1] Feldman and Audretsch (1999) used the United States Small Business Administration's Innovation Data Base that consists of innovations compiled from the announcements of new product in manufacturing trade journals. They found evidence supporting the diversity thesis of Jacobs. Glaeser, et al. (1992) provide indirect evidence by looking at employment growth between 1956 and 1987 across specific industries in a given city. They found that metropolitan areas that are industrially diversified grow more rapidly, specialized areas did not. In contrast, Henderson, Kuncoro and Turner (1995) examine employment growth rates in five traditional capital goods industries for 224 standard metropolitan statistical areas (SMSAs) from 1970 to 1987 and found that growth was positively correlated with a high past concentrations in the own industry, supporting the MAR view. However, these authors note that, unlike traditional manufacturing, for firms in high-technology industries past industrial diversity increased the probability that an SMSA attracted a high-tech industry, suggesting that Jacobs' externalities play an important role in the development of the high-technology sector.

Economists have also debated the effects of an area's market structure on the rate of innovation and growth. Chinitz (1961) and Jacobs (1969) believe that the rate of innovations is greater in cities with competitive market structures. For example,

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[1]Pred (1966) also stressed the dynamic advantages of diversity.

according to Jacobs, local monopolies have the resources to stifle innovations by competing firms whereas more competitive local environments foster the introduction of new methods and new products. More recently, Porter (1990) argued that when local economies are competitive the innovations of local firms are rapidly adopted and improved by other neighboring firms. In contrast, he believes that local monopolists tend to rest on their laurels rather than risk innovation.

Alternatively, according to Glaeser et al. (1992), the MAR view predicts that local monopoly is superior to local competition, because innovating firms recognize that a portion of their ideas will be imitated by neighboring firms without compensation. Firms in locally competitive environments may therefore invest less in research and development because they do not reap full benefit of such investment. Thus, local monopoly may foster innovation because firms in such environments have fewer neighbors who imitate them. Prior evidence favors the view expressed by Chinitz and Jacobs as opposed to the MAR view. Feldman and Audretsch (1999) find that local competition is more conducive to innovative activity than is local monopoly. There is also indirect evidence on the issue offered by Glaeser, et al. (1992) finding that local competition is more conducive to city growth than is local monopoly.

THE MODEL

Consider the following aggregate production function for MSA i:

$$Y_{i,t} = A_{i,t} \bullet F(K_{i,t}, L_{i,t}) \qquad (1)$$

Where: $Y_{i,t}$ represents output in location i at time t, $K_{i,t}$ represents capital stock in i at t, $L_{i,t}$ represents labor in i at t, and $A_{i,t}$ represents Hicks-neutral productivity that differs across locations.

Differentiating (1) with respect to time yields:

$$\frac{dy_i}{dt} = F_i(K_i, L_i)\frac{dA_i}{dt} + A_i\frac{\partial F_i}{\partial K_i}\frac{dK_i}{dt} + A_i\frac{\partial F_i}{\partial L_i}\frac{dL_i}{dt}$$

Which can be rearranged to yield a growth accounting equation:

$$\dot{Y}_i = \dot{A}_i + \eta_K \dot{K}_i + \eta_L \dot{L}_i \tag{2}$$

Where dots over a variable indicate time derivatives, and η_K and η_K are the elasticities of output with respect to changes in capital and labor, respectively. The main argument of this paper is localized knowledge spillovers influence the growth of productivity:

$$\log \dot{A}_i = a_i + b_i \log S_i \tag{3}$$

Where S_i represent knowledge spillover in location i, and b_i represents the strength of the spillover in location i. The term a_i is a vector reflecting all other productivity factors in location i. Furthermore, S_i is assumed to be external to any individual firm in i, but internal to the firms' local economy. We make the assumption that knowledge spillovers depend on the average value of employment density in location i:

$$\log \dot{A}_i = a_i + b_i \log\left(\frac{E}{N}\right)_i \tag{4}$$

Where E represents total employment in location i, and N is land area in i. Thus, employment in an MSA is assumed to be distributed equally across all the acres in the MSA.

Glaeser (1996) points out that “urban proximity, the closeness of innovations to one and another, the closeness of innovations towards the sources of potential demand, and the closeness of innovators to suppliers and critics, has served throughout history as an engine by which ideas moved across individuals.” For example, many semiconductor firms have located their research and development facilities in Silicon Valley because the area provides a nurturing environment where semiconductor firms can develop new products and new production technologies. Often information about current developments in the semiconductor industry is shared on an informal basis. Saxenian (1994) describes how gathering places, such as the Wagon Wheel Bar located only a block from Intel, Raytheon, and Fairchild Semiconductor, “served as informal recruiting centers as well as listening posts; job information flowed freely along with shop talk.” Other examples of “high-tech hot spots” include the Route 128 Corridor in Massachusetts, and the Research Triangle in North Carolina, and biotechnology research and medical technology software companies in suburban Philadelphia.

Examples are not limited to the high tech industry. For example, the geographic concentration of the motion picture industry in Los Angeles offers a network of specialists (directors, producers, scriptwriters, script doctors, set designers, etc.), each of whom focuses on a narrow niche within the industry. The network creates an atmosphere that encourages collaboration, experimentation, and shared learning among individuals and firms. In the medical field, research facilities and teaching institutions have concentrated along York Avenue on Manhattan’s Upper East Side to enhance knowledge spillovers among researchers at different institutions. York Avenue is home to Memorial Sloan-Kettering Cancer Center, Rockefeller University and Hospital, and New York

Presbyterian medical center. Porter (1990) cited the Italian ceramics and ski boot industries and the German printing industry, among others, as examples of geographic concentrated industries that grew rapidly through the continual introduction of new technologies.

There are also examples of knowledge spillovers across firms in different industries. McDonald (1997) has pointed out that both Jacobs (1969) and Jackson (1988) have noted that Detroit's shipbuilding industry was the critical antecedent leading to the development of the auto industry in Detroit. In the 1820s Detroit mainly exported flour. Because the industry was located north of Lake Erie along the Detroit River, small shipyards developed to build ships for the flour trade. This shipbuilding industry refined and adapted the internal-combustion gasoline engine to power boats on Michigan's rivers and lakes.

As it turned out, the gasoline engine, rather than the steam engine, was best suited for powering the automobile. Several of Detroit's pioneers in the automobile industry had their roots in the boat engine industry. For example, Olds produced boat engines, and Dodge repaired them. In addition, a number of other industries in Michigan supported the development of the auto industry, such as the steel and machine tool industries. These firms could produce many of the components required to produce autos.

EVIDENCE

Since data on innovations are not generally available at the local level, patents per capita in an MSA are used as our measure of innovation. Using patents as a measure of innovations has shortcomings since some innovations are not patented and patents differ enormously in their economic impact. Nonetheless, patents are a useful measure of the generation of ideas in cities. We estimate a cross-sectional model where the rate of patenting in an MSA is regressed on several alternative measures of local employment density (defined below) and a number of other variables thought to affect patenting at the MSA level as discussed in the text. The sample consists of 296 of the 313 MSAs and primary metropolitan statistical areas (PMSAs).[2] Specifically, we estimate the following equation:

$$P_i = C + a_1 D_i + a_2 E_i + a_3 U_i + a_4 PCTLG_i + a_5 PCTMAN_i + a_6 PCTCOL_i + a_7 HI_i + a_8 COMP_i + a_9 EMPGT_i$$

where

$P_i =$ Average patents per capita, 1990-99 in MSA i

$D_i =$ The density of employment in 1989 in the ith MSA's urbanized area.
Two alternative measures are used: in model (1) employment density = MSA employment divided by square miles in the MSA's urbanized area; in model (2) employment density = employment in the county containing the MSA's central city divided by square miles in the urbanized area.

$E_i =$ 1989 level of employment in MSA i

$U_i =$ University R & D spending in science and engineering programs, average for the period 1989-91 in MSA i

$PCTLG_i =$ Percent of firms with 1,000 or more employees in 1989 in MSA i

$PCTMAN_i =$ Manufacturing share of total employment in MSA i, in 1989

$PCTCOL_i =$ Percent of 1990 population with at least a college degree in MSA i

[2]Since PMSAs are treated as MSAs in this study, we refer to them as MSAs. We do not consider consolidated metropolitan statistical areas (CMSAs) in this study. A 1983 definition for MSAs and PMSAs is used in the analysis.

HI_i = Herfindahl Index $= \sum_{j=1}^{9} \left(s_{j,i} \right)^2$ Where $s_{i,j}$ is the share of industry j in MSA i.

$COMP_i$ = Measure of local competition = Total number of firms in MSA i divided by total employment in MSA i

$EMPGT_i$ = employment growth rate in MSA i during the period 1979-89.

The dependent variable refers to patents per person averaged over the period 1990-99, whereas the independent variables are at 1989 or roughly beginning-of-the-period values.[3] This reduces the simultaneity and reduces direction of causation issues, since the value of the dependent variable that is averaged over the 1990s is not likely to affect beginning-of-period values of the independent ones. We chose metropolitan statistical areas (MSAs) and primary metropolitan statistical areas (PMSAs) as the main geographical unit for our analysis, since MSA and PMSAs boundaries reflect the extent of local labor markets.

To investigate the relationship between innovation and density, we need a measure of local employment density. Employment density varies enormously within an MSA. Typically, employment density is highest in the central business district (CBD) of an MSA's central city and generally falls off as we move away from the CBD. An urbanized area is defined as the highly dense area within an MSA.[4] If knowledge spillovers are important, it's likely that urbanized areas with high-employment density

[3]We use utility patents granted to U.S. inventors. Patent data were provided at the county level and aggregated to MSAs based on the 1983 MSA definitions. The geographic distribution of patents is based on the residence of the inventor whose name appears first on the patent and not the location of the inventor's employer.

[4] The Census Bureau defines an urbanized area as one with a total population of at least 50,000, consisting of at least one large central city and a surrounding area with a population density greater than 1000 people per square mile.

would account for most of them.

Ideally, we want to use employment density in the urbanized area of the MSA to investigate the relationship between density and innovation. While we can measure the land area of the urbanized part of an MSA, employment data are not available for urbanized areas of MSAs. So we used two alternative measures for local employment density. Our first measure for local employment density assumes that all employment in an MSA is located within the MSA's urbanized area. This assumption means that our first measure overstates both employment and local employment density. Our second measure is the ratio of employment in the county containing the MSA's central city to square miles in the urbanized area of the MSA. Since the urbanized area is defined to include the MSA's central city *and* the highly dense surrounding areas, our second measure understates both employment and employment density in urbanized areas. By using these alternative measures for local employment density, we believe that the two estimates of the effect of local employment density on the rate of patenting obtained in our analysis will capture the true effect of density on innovation.[5] As Figure 1 shows, data for the 1990s on 270 MSAs (MSAs for which urbanized areas are defined) reveal a positive association between patents per capita and local employment density.

We also include MSA employment size in 1989 to control for both "scale effects" and for localized concentrations of employment/production that may be the result of static agglomeration economies.[6] The scale effect takes into account the fact that larger economies (in terms of employment) devote more resources to innovation and therefore

[5]As might be expected, the two alternative measures of local employment density are highly correlated; the simple correlation is 0.91.
[6]This article uses *private* non-farm employment as reported in *County Business Patterns*.

generate more patents per capita for a given level of density. Feldman and Audretsch (1999) find that innovative activity increases with MSA size.

R&D spending in science and engineering programs at colleges and universities is included separately, since many authors have found spillovers from such spending and innovative activity at the local level (see for example, Anselin, Varga and Acs (1997), Jaffe (1989), and Audretsch and Feldman (1996)).[7] Similarly, since large firms tend to spend proportionately more on private R&D than do smaller firms, the percentage of an MSA's firms with 1000 or more employees is included separately to capture the presence of large firms on patent activity. In addition, manufacturing share of total MSA employment is also included in the list of independent variables to control for the fact that more patents originate in manufacturing than in other sectors.[8] The percent of an MSA population with at least a college degree is included to separately account for the role of educational attainment and patenting.

We need to develop a measure of industrial diversification of a local area or lack of it to gauge the extent to which the rate of MSA patenting is related to MAR or Jacobs externalities. This measure will be based on a Herfindahl index. Specifically, the measure of diversification or inversely specialization is calculated by squaring and summing the share of MSA employment accounted for by each of seven industries (V_j):[9]

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[7]The data used for university research expenditures are compiled from NSF Survey of Scientific and Engineering Expenditures at Universities and Colleges and Federally Funded Expenditures at R&D Development Centers. The data were averaged for the period 1989-91. The data on firm size were obtained from *County Business Patterns*.

[8]Data to construct the percent large firm variable are obtained from *County Business Patterns*.

[9]The seven industries are manufacturing; transportation, communications, and public utilities; wholesale trade; retail trade; services; finance, insurance, and real estate; and other industries. Construction's share of private non-farm employment was not included in the calculation of the index because of disclosure problems associated with this variable for some MSAs in our sample. We also controlled for industry-mix differences across MSA by including the share of total MSA employment accounted for by industry. With the exception of manufacturing, differences in industry did not significantly influence patents per capita.

$$HI_{i,j} = \sum_{j=1}^{7} \left(V_j\right)^2$$

The index assigns weights of unity to each industry's share of employment and the squaring means that the larger industries contribute more than proportionately to the overall value of the index. Thus, as the index increases in value for a given MSA this implies that the MSA is more highly specialized or less diversified industrially.

We need a measure of a local area's market structure to test whether knowledge spillovers are greater if an MSA is competitive. Following Glaeser, et al. (1992), the total number of firms per worker in an MSA is used as a measure of market structure, i.e., an MSA is taken as locally competitive if it has many firms per worker. [10] Finally, employment growth during the period 1979-89 is included to control for any independent effect that local growth may have had on patent activity.

Findings. Table 1 shows the summary statistics for the variables used in the analysis. The table gives the mean, standard deviation and minimum and maximum values for the variables. For example, the table shows patents per 10,000 people, which is the dependent variable used in the regressions to follow. The mean value for patents per 10,000 people is 2.265 for the 296 MSA in our sample. The San Jose, California MSA ranked first, averaging almost 18 patents for every 10,000 people, while the Laredo, Texas MSA was last, with 0.061 patents for every 10,000 people. As the table shows, the mean, standard deviation, minimum, and maximum statistics for the two alternative measures of local employment density have quite similar values. As expected,

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Therefore, only manufacturing share of total MSA employment is included in the regressions reported in this article.

[10]Data for this variable are obtained from *County Business Patterns*.

the mean of 1327 for urbanized area central city county employment density variable is less than the mean of 1476 for urbanized area MSA employment density variable. In general, Table 1 shows substantial variation in all other variables used in the model.

Figure 1 plots the log of patents per capita against the log of local employment density (log of the ratio of MSA employment to land in the urbanized area). The figure shows a moderately positive correlation between patenting and density; the correlation coefficient is 0.50. Figure 2 plots the log of patents per capita against the log of local employment density (log of the ration employment in the county containing the central city to land in the urbanized area). The figure also shows a moderately positive correlation between patenting and density; the correlation coefficient is 0.43.

The model was estimated in log form using ordinary least squares methods with White robust standard errors to take heteroskedasticity into account. The results of the regression are presented in Table 2. As indicated, one problem is that employment data for urbanized areas are not available. Therefore, we must estimate it. In model (1) we assume that all employment in an MSA is located within its urbanized area. This assumption overstates both employment and employment density in urbanized areas. In model (2) we assume that all employment in an MSA is located within the county that contains the MSA's central city. This assumption understates both employment and employment density in urbanized areas.[11] As the results of both models show, the effect of employment density on patenting is positive and highly significant. These findings suggest the importance of close spatial proximity in promoting spillovers and fostering

[11]On average, the county containing an MSA's central city accounts for 84 percent of MSA employment.

innovation.[12] A number of other variables in the model have the expected positive association with the rate of MSA patenting, including MSA employment size, percent of MSA firms with 1000 or more employees, percent of MSA employment in manufacturing, and the percent of MSA population with a college education. One anomaly is that university R&D spending has the wrong sign (negative, which suggests that increased spending by local universities on R&D in science and engineering programs is associated with fewer patents per capita in an MSA), and this variable is significant in Model (1). Jumping ahead, the universities spending on R&D variable remains negative, but is insignificant, in the fixed-effects version of the model presented in the next sub-section. Finally, the R^2 statistic, measuring the goodness of fit, shows that the models explain a little less than 60 percent of the variation in MSA patents per capita (this is a good fit for a cross-MSA model).

Even if we accept the view that dense local areas serve as centers for the exchange of ideas, we come back to the issue of whether the rate of exchange is enhanced in industrial environments that are diverse (for example, New York City) or in more specialized ones (for example, Silicon Valley). Feldman and Audretsch (1999) and Glaeser, et al. (1992) find evidence supporting the diversity thesis of Jacobs. Conversely, we find little evidence that diversity, or lack of it, is an important factor in determining the rate of patenting activity in metropolitan areas in the 1990s. The coefficient on the

[12] We also run a version of the model using MSA employment density in place of the local employment density variables. The MSA employment density variable was positive but not significant. In our sample, MSA employment **size** and MSA employment **density** are highly correlated (correlation coefficient of 0.75). Thus these two variables tend to “fight” one another for explanatory power when both are included in the same regression. Since MSA employment size and the employment density variables based on urbanized area definitions are only weakly correlated (correlation coefficient of 0.38 when MSA employment is used and 0.21 when employment in the county containing the central city is used) we obtain independent effects for each of these variables on patenting when both are included in the same regression.

Herfindahl index is not significant, suggesting that the degree of industrial specialization of an MSA does not have an impact on MSA patenting.

Finally, we look at the evidence on whether the creation of ideas is greater in competitive local environments characterized by many small firms than in local economies dominated by a few large firms. Recent studies find evidence that local competition is more conducive to innovative activity (Feldman and Audretsch (1999)) and growth (Glaeser et al (1992)) than is local monopoly. Counter to these studies, and to the views of Chinitz and Jacobs, we find that overall patenting is not related to local competition, or lack of it. The firm per employee variable is not significant, suggesting that competitiveness of the local economy does not appreciably affect MSA patenting activity.

Fixed Effects Model. The regression results reported in Table 3 included dummy variables designed to see if specific regions of the country contributed more or less to MSA patenting. Each MSA was classified into one of eight broad regions (New England, Mideast, Great Lakes, Plains, Southeast, Southwest, Rocky Mountain, and Far West). According to the results reported in Table 3, the estimated coefficient on the local employment density variable, reported in column (1) and column (2) are positive and highly significant. However, the estimated value for both versions of the local employment density variable falls in the fixed-effects versions of the model. The estimated value in Model (1) falls from 0.42 without fixed effects to 0.31 in the fixed-effects version of the model, while falling from 030 to 0.21 in Model (2). The findings suggest that the number of patents per capita was, on average, 20 percent to 30 percent higher in an MSA whose local economy was twice as dense as that of another MSA.

Since local employment density varies by more than 2000 percent across locations in the sample, the implied gains in patents per capita due to urban density are substantial. For example, in 1989, the average urbanized area in our sample had about 1500 jobs per square mile (assuming all jobs in the MSA are located inside its urbanized area). Toledo, Ohio; Eugene, Oregon; and Omaha, Nebraska are three MSAs with local employment density at about this average level. These three MSAs averaged 1.8 patents per 10,000 people during the 1990s. If their local employment density were to double, the model predicts that patents would rise, on average, to 2.3 per 10,000 people. Thus, these findings are consistent with the widely held view that the nation's densest locations — its central cities and their dense inner-ring suburbs — play an important role in creating the flow of ideas that generate innovation and growth.

We found that MSA patents were higher in the Mideast and Great Lakes regions relative to the Southeast region; the coefficients for the other regions were not statistically significant. The estimates of the effect of local density variables on MSA patenting were somewhat lower when regional dummy variables are included in the regressions.

Alternative explanations for positive correlation between patents per capita and density. One potential concern is that the rate of patenting may be greater in denser locations for reasons other than knowledge spillovers. For example, it's possible that in urban areas it's harder to keep information secret, so firms resort to patents. Based on a survey questionnaire of R&D at 1478 manufacturing firms in 1994, Cohen, Nelson, and Walsh (2000) report that manufacturing firms typically protect the profits from their innovations with a variety of mechanisms, including patents, secrecy, and lead-time advantages. (The study is referred to as the Carnegie Mellon Survey (CMS).) Furthermore, the majority of manufacturing firms surveyed indicated that they use secrecy and lead-time advantages more heavily than patents. In the survey, secrecy ranked first or second for product innovation in 24 of the 33 industries considered.

More important for our purposes, surveyed firms indicated that concern over information disclosed in patents is a major reason many choose not to pursue a patent. Current laws require patents to describe an invention in precise terms. In addition, there are high fixed costs associated with preparing a patent application. Trade secrets, however, avoid these fixed costs, but preventing disclosure of the secrets incurs expenses. Although the CMS does not consider the location of the firms in its sample, its findings nonetheless suggest that firms may be forced to rely on patenting to a greater extent in dense areas because it is harder and more costly to maintain secrecy there than in less dense areas. Thus, it may be this increased difficulty in maintaining secrecy, and not knowledge spillovers, that account for the positive correlation between patents per capita and metropolitan density.

Unfortunately, we cannot distinguish between the effects of knowledge spillovers and those of secrecy in the empirical model.[13] While secrecy may account for some portion of the positive association between patents per capita and density, it is unlikely that it would completely "crowd out" the effects of knowledge spillovers. In addition, the CMS was limited to manufacturing firms engaged in R&D activity. Hunt (2001) has shown that firms in other parts of the economy, such as the financial services, computer programming, and data processing industries, are increasingly turning to patents to

[13]At this time, data that would allow us to discern the role of knowledge spillovers and that of secrecy in patent activity in dense local areas are not publicly available.

protect more abstract inventions such as computer programs. Nonetheless, the extent to which firms opt for patents in lieu of secrecy in dense local areas is an issue worthy of future research.

CONCLUSION

The extraordinary recent growth in productivity and jobs in the United States has been attributed in part to innovations. This article has shown that patent activity of a metropolitan area is positively related to the density of its highly urbanized portion of MSAs. We find that the elasticity of the patent rate with respect to local employment density is between 0.2 to 0.3 in the fixed-effects version of our model. This implies, on average, that rate of patenting is 20 percent to 30 percent greater in an MSA with a local economy that is twice as dense as the local economy of another MSA. Since local employment density doubles more than four times in the sample, the implied gains in patents per capita due to urban density are substantial. Thus, these findings confirm the widely held view that the nation's densest locations play an important role in creating the flow of ideas that generates innovation and growth.

Our findings, as well as the findings of other studies, offer little support for the MAR view that specialization and local monopoly foster innovation. The evidence is mixed on the Jacobs view that the rate of innovation is higher in industrially diverse and competitive local economies. While we find little evidence that the rate of innovation is greater in diverse and locally competitive environments, studies by Glaeser, et al. (1992) and by Feldman and Audretsch (1999), however, report results favorable to Jacobs' view.

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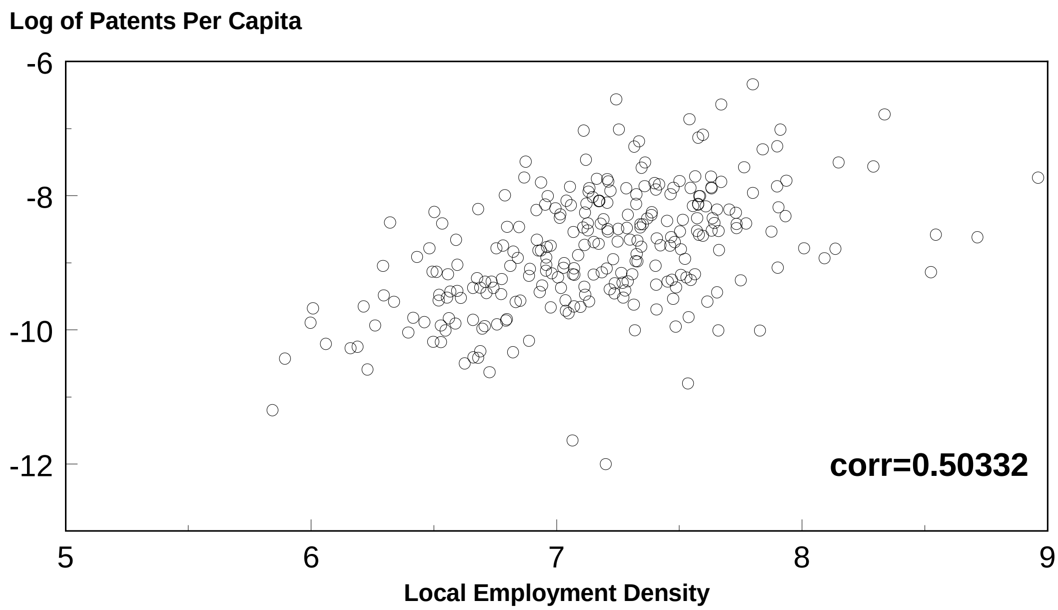
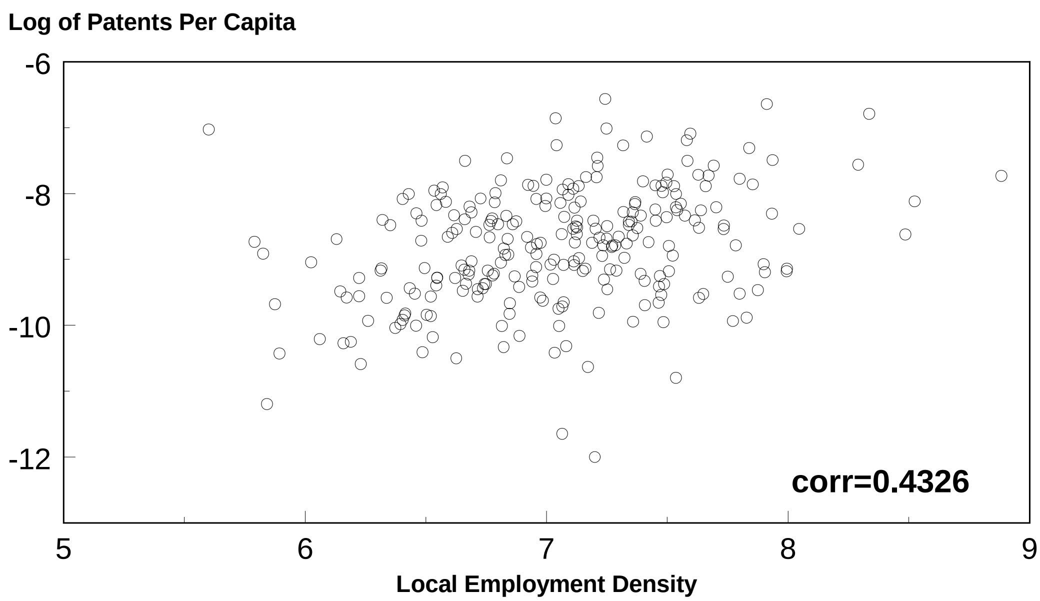
Figure 1
Correlation Between Log of Patents Per Capita and Log of Local Employment Density



(Based on MSA Employment.)

Figure 2
Correlation Between Log of Patents Per Capita and Log of Local Employment Density



(Based on County Central City Employment.)

Table 1: Summary Statistics					
	Obs.	Mean	SD	Min.	Max.
Patents Per Capita	296	0.0002265	0.0002255	0.06	0.001756
Urbanized Area MSA Employment Density	270	1476.5	855.0	345	7802
Urbanized area MSA Employment Density	257	1327.4	806.1	271.1	7215.9
1989 Employment	296	246,971	447,356	3082	3,778,867
University R&D Spending (1000)	296	47,401.0	124,481.4	0.000	1,118,692.0
Percent of firms with 1,000 or more Employees	296	0.0009	0.0005	$0.1e^{-06}$	0.0028
Percent Mfg.	296	0.2164	0.0927	0.0299	0.5691
Percent College Educated	296	0.1967	0.0674	0.0730	0.5710
Herfindahl Index	296	0.3028	0.0242	0.2633	0.3873
Firms per Employee	296	0.0686	0.0136	0.0379	0.1217
Employment Growth, 1979-89	296	0.2063	0.1922	-0.5064	0.7671

Table 2: The Determinants of Patents Per Capita, Averaged over the Period 1990-99.		
	(1)	(2)
1989 Employment	0.2872***	0.3388***
Urbanized area MSA Employment Density	0.4212***	
Urbanized area Central City County Employment Density		0.2964***
University R&D Spending	-0.0129**	-0.0015
Percent of Firms with 1,000 or more Employees	250.5**	263.5***
Percent Mfg.	3.46***	3.98***
Percent College Educated	7.06***	7.22***
Herfindahl Index	0.6189	0.8868
Firms per Employee	0.4163	0.4602
Employment Growth, 1979-89	-0.2086	-0.1976
Constant	-15.6***	-15.0***
No. of Obs.	270	257
R^2	0.5991	0.5722

Table 3: The Determinants of Patents Per Capita, Averaged over the Period 1990-99. (Fixed Effects Model)		
	(1)	(2)
1989 Employment	0.2985***	0.3368***
Urbanized area MSA Employment Density	0.3058***	
Urbanized area Central City County Employment Density		0.2056***
University R&D Spending	-0.0086	-0.0102
Percent of Firms with 1,000 or more Employees	202.1**	227.9***
Percent Mfg.	3.66***	4.12***
Percent College Educated	6.63***	6.60***
Herfindahl Index	1.4785	1.8249
Firms per Employee	0.5298	0.5654
Employment Growth, 1979-89	0.1018	0.1253
Far West	0.1060	0.1130
Great Lakes	0.5431***	0.5198***
Mideast	0.3782**	0.4381***
New England	0.2545	0.2571
Plains	0.1153	0.1124
Rocky Mountain	0.3505	0.3433
South West	-0.0958	-0.1609
Constant	-13.8***	-13.1***
No. of Obs.	270	257
R^2	0.6138	0.6169

Table 4: The Determinants of Patents Per Capita, Averaged over the period 1997-99, Lagged Dependent Variable (Fixed Effects Model)		
	(1)	(2)
1989 Employment	0.0369	0.0365
Patents per capita, 1990	0.7201***	0.7341***
Urbanized area MSA employment density	0.1577**	
Urbanized area Central city county employment density		0.05227
University R&D Spending	-0.0020	-0.0009
Percent of firms with 1,000 or more employees	32.6	6.5
Percent Mfg.	0.6162	0.8190
Percent college educated	2.29***	2.32***
Herfindahl index	0.2631	0.4718
Firms per employee	-0.3209	-0.4834
Employment Growth, 1979-89	0.5844***	0.6203***
Far West	0.1243	0.1769
Great Lakes	0.1164	0.0826
Mideast	0.2260**	0.2482***
New England	0.1213	0.1266
Plains	0.0977	0.0885
Rocky Mountain	0.4766	0.4973**
South West	0.0507	0.1817
Constant	-0.5863	-4.5***
No. of Obs.	268	255
R^2	0.6138	0.5069