Estimating Universities' Contributions to Regional Economic Development: The Case of the U.S.

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1 Introduction

Since the mid-1980s, academic interest in the relationship between knowledge production within a region and the region's economic growth and development performance and prospects has burgeoned. The reasons for this increased interest include dramatic changes in the global economy and conditions of regional competitiveness, the increased importance of knowledge inputs in the production of a wide range of goods and services, and more recently advances in "the new growth theory".

The relatively severe economic downturn of 1981–1982 hit the traditional manufacturing sectors particularly hard. In response, economic development officials at the state and regional levels began investing in a variety of programs and institutions aimed at strengthening their regions' knowledge infrastructure. Public universities were often the primary institutional recipient for many of the investments in knowledge infrastructure. Faced with budgetary squeezes, leaders at many public universities were only too eager to accept responsibility (and the funding that came with it) for adding economic development to their traditional missions of teaching, research, and public service. The passage of the Bayh–Dole Act of 1980 gave universities an even larger incentive to engage in entrepreneurial activities, by giving them intellectual property rights on patentable inventions originally stemming from federal government-sponsored research.

The purposes of these public investments in knowledge infrastructure have varied among states and regions, depending upon particular economic conditions and perceived needs. Generally, however, they have focused on attracting, nurturing, and retaining high tech industries and innovative firms, to provide existing residents with the range of skills and competencies they will need to be productive in the knowledge economy, and to help the region sustain its competitiveness into the future. Beliefs about the importance of such investments tended to be based neither upon sound empirical evaluations nor theoretical arguments. Instead they emanated from a few well-known and celebrated "success" cases such as Silicon Valley in California, Route 128 in Massachusetts, the Research Triangle in North Carolina: "We can be the region spawning the next Apple Computer." There was also a tendency for state and regional

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development officials to play "follow the leader," so as not to risk being the one left behind (Atkinson, 1989).

For any significant public investment, there is always a range of questions about the magnitude of impacts, their distribution, and the investment's effectiveness in achieving desired objectives. In the particular case of investments in the production of knowledge and knowledge infrastructure, the expected regional economic impacts revolve around the nature of spatial spillovers and other forms of externalities generated from knowledge producing organizations. If we focus on universities as the dominant type of knowledge producing organizations,[2] the following questions should be addressed:

1. To what extent do institutions of higher education, and research universities specifically, generate regional economic development outcomes that would otherwise not occur?
2. Which university-based activities, e.g. teaching, basic research, extension and public service, technology transfer, technology development, businesses spinning off from university research, etc, are most responsible for any net regional economic development impacts from the presence of universities?
3. Through what mechanisms, or channels, does knowledge production – broadly considered – within universities lead to economic development outcomes in the surrounding region? Is it, for example, through economic transactions between actors or units within the university and external organizations, through spillovers, or through milieu effects, which are particular kinds of localization economies?
4. What are the critical internal and external factors that condition the contribution of knowledge-producing organizations to regional economic development, and determine the share of total economic development impacts that are retained within the region, vis-à-vis the rest-of-the-world?

In this paper we focus on addressing the first, the second, and the fourth questions. Our empirical analysis employs a quasi-experimental design with a large sample of metropolitan regions in the U.S. The results provide us with some indirect insights on the third question, the modes of transmission of impacts from universities to the larger region.

The paper is organized into six sections. The next section lays out conceptually the different ways universities potentially may contribute to regional economic development. The third section provides a brief, critical review of the two primary methodological approaches that have been used to estimate university impacts on regional economic development, and introduces the advantages of using a quasi-experimental design. In the fourth section we describe the study population, the measures, the data, the hypotheses, and the models used in the present study, while the empirical results are presented in the fifth section. The sixth and last section is a conclusion that focuses

[2]Other knowledge producing organizations include federal laboratories and the full array of corporate and non-profit R&D labs. In terms of total U.S. R&D expenditures, however, universities comprised 14.0 percent in 1998 (National Science Board, 2000).

on the nature of university spillovers to their regional environment, given the empirical results.

2 Outputs and Potential Impacts of Research Universities

The literature on the economics of knowledge production and innovation, on knowledge spillovers, and on the changing role of institutions of higher education together suggest there is a wide range of ways that universities potentially can contribute directly and indirectly to regional economic development. The modern research university, at least in the United States and increasingly in Western Europe, can be considered as a multiproduct organization. Within legal, cultural, and political constraints, the research university can choose its optimal product mix in response to perceived changes in its markets and the availability and prices of its inputs (unlike corporate R&D organizations, universities do not consider changing locations as responses to changing market conditions).

Goldstein, Maier, and Luger (1995) synthesized a wide range of literature on institutions of higher education and identified and described the range of products, or outputs, from modern research universities. They then suggested how each of these types of outputs may potentially lead to specific economic development impacts. The outputs include: (i) knowledge creation, (ii) human capital creation, (iii) transfer of existing know-how, (iv) technological innovation, (v) capital investment, (vi) provision of regional leadership, (vii) coproduction of the knowledge infrastructure, and (viii) coproduction of a particular type of regional milieu. The potential impacts include: productivity gains, business innovation, new business start-ups, an increase in regional economic development capacity (for sustained, long-term development), regional creativity, and direct and indirect spending impacts. The hypothesized relationships between the university outputs and the hypothesized regional development impacts can be seen in Figure 1.

3 Available Methodological Approaches

The literature suggests there are two primary ways to investigate the link between knowledge production and regional economic development: the case study, and econometric models of knowledge production and spillovers.

3.1 The Case Study

We can trace case studies of the economic impact of specific universities in the published literature at least back to the early 1970s. These case studies attempt to estimate the contribution of a particular institution of higher education to the regional economy in one of two typical ways. In the first, a regional input-output model is used to estimate the direct and indirect spending effects of the organization on the region's output, earnings, and employment. In the second, a sample of other businesses or organizations in the region are asked in a questionnaire what the perceived importance of the

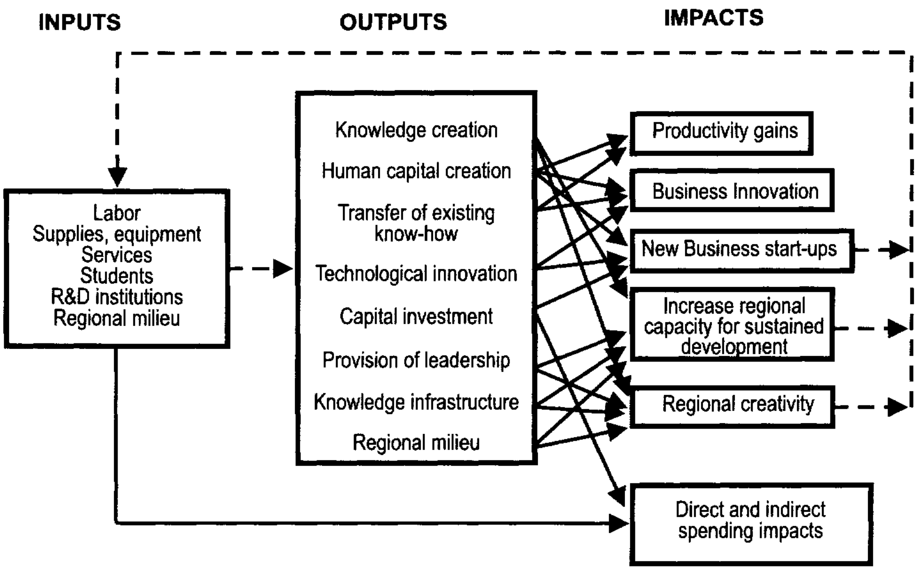

Figure 1: University outputs and expected economic impacts (Source: Goldstein, Maier and Luger, 1995).

university was to the location decision, productivity and competitiveness, innovation, and output levels of the respondent's organization.

A recent article by Thanki (1999) reviews much of the case study literature, particularly in the experience of the United Kingdom. The author finds that such studies todate have not been able to capture many of the potential ways that institutions of higher education can lead to regional economic development, either because of a too narrow understanding of how regional development occurs, or because of the limitations of the techniques used. For instance, regional input-output models and other multiplier techniques can only capture economic growth that stems from backward linkages induced by an institution of higher education's spending. The reliance on only such techniques fails to take into account the unique qualities of knowledge as a product of such organizations, essentially treating a university no differently from any other kind of organization that hires and pays labor and purchases supplies and equipment from both regional and outside sources. Felsenstein (1994a) reviews a large number of economic impact studies conducted in the U.S. using input-output and related multiplier techniques. For the most part, these studies suffer from the same set of limitations as discussed by Thanki (1999).

Within the case study framework, a more eclectic set of data collection and analytic techniques have been used to try to estimate a wider range of putative regional economic effects of universities, in addition to those measured by input-output models. Several researchers (Brett et al., 1991, Smilor et al., 1990, Ko, 1993, Steffenson et al., 2000) have focused on "counting" the number of spin-offs from university research centers and academic departments, using newspapers and the regional business press, as well as personal interviews as sources. Luger and Goldstein (1991) and Goldstein and Luger (1992, 1993) have used targeted questions sent in a questionnaire to a stratified sample of high tech companies recently located in a region to estimate to what extent the region's research universities were an important factor in their regional location decision. By asking the counterfactual, "If the University of . . . were not in the region, how likely would you have located your business in this region: (1) Very likely, (2) Likely, (3) Perhaps, (4) Unlikely, (5) Very unlikely," and then applying a specific probability to each response, the researchers were able to estimate the total employment and output in the region's high tech sector that otherwise would not have been located there.

Goldstein and Luger (1992) also have estimated the human capital impacts on a region of a university by linking historical student registration and alumni records to estimate the percent of graduates, by degree and discipline, who have remained and been employed within the region over time. Felsenstein (1994b) estimates the amount of university-induced migration to a region (that would not have otherwise occurred) using Keynesian-type multipliers.

Saxenian's (1994) comparative case studies of Silicon Valley and Route 128 in Massachusetts, while not attempting to measure the impact of specific universities on regional development, tries to explain the difference in economic performance and success between the two areas by using ethnographic techniques focusing on the extent and qualities of inter-organizational linkages and collaborations within the respective regions.

In summary, the principal strengths of the case study approach are: (1) its flexibility in being able to collect primary data through surveys and interviews, and documentary evidence in the form of internal reports, in order to measure, or count, particular kinds of university outputs and some of the associated impacts; (2) to be able to generate information about the internal organization and culture of a particular university in order to be able to relate these internal attributes to effectiveness in contributing to regional economic development; (3) being able to generate information about the soft and "fuzzy" side of how universities may stimulate economic development: through the provision of leadership and the co-production of a creative milieu, concepts that are difficult to measure. The often intensive data gathering effort to estimate the spending impacts of the university on the regional economy with the use of input-output and related multiplier techniques is almost always conducted within a case study approach. The case study approach is most appropriate for counting or estimating incidences of technology transfer, technological innovation (e.g. in the form of patents issued and licenses sold), capital investment, and number of business spin-offs.

The principal weakness of the case study approach is solving the "attribution" problem, i.e. controlling for other putative factors when trying to make causal inferences between university activities and regional economic development outcomes. This is most problematic for estimating indirect impacts such as regional productivity gains, increases in innovative activity in the region, increased economic development capacity, and regional creativity. In principle one could conduct multiple cases studies using a standard set of data and techniques in order to mitigate the inability to statistically control for other intervening factors, but this is likely to be impractical owing to the relatively large cost of conducting individual case studies. In several of the case studies discussed above, researchers have asked respondents about the "perceived" impacts, or "perceived importance" of the university, or have constructed counterfactuals, but the use of such data and techniques carries with them some obvious and significant validity threats.

3.2 Econometric Models of Knowledge Production and Spillovers

More recently, economists have tried to assess the economic impact of new innovation such as that produced at a university by using econometric models. Early models focused on production functions that contained an R&D variable. Griliches (1979) proposed a specific knowledge production function assumed to be Cobb–Douglas in form, relating Y, some output, to labor, capital and knowledge, measured by R&D expenditures. This work was based on the empirical work of Solow (1957), which showed the existence of a latent variable besides capital and labor in aggregate production functions, and Arrow (1962), who described the impact of learning (gaining knowledge) on the production function.

Jaffe (1989) modified Griliches' knowledge production function to the form that is generally used by researchers today: $LogK = \alpha_0 + \alpha_1 logRD + \alpha_2 logURD + \epsilon$ where K is some measure of innovation, *RD* is industry research and development expenditures and *URD* is university research and development expenditures. Jaffe found "geographically mediated spillovers from university research to commercial innovation." A significant effect of university research on corporate patents was found, particularly in drugs, medical technology, electronics, optics and nuclear technology. He states that university research appears to have an indirect effect on local innovation by inducing industrial research and development spending.

A number of researchers have modified and expanded this model in the last twelve years or so. Jaffe, Trajtenberg and Henderson (1993) followed up this work by looking at the geographic location of patent citations to understand the extent to which knowledge spillovers are geographically localized. They found that citations to domestic patents are more likely to be domestic, and more likely to come from the same state and MSA as the cited patents. Acs, Audretsch and Feldman (1994) used the Griliches–Jaffe model to understand the degree to which university and corporate R&D spills over to small firms as compared to large firms. They found that university spillover was more important to small firms than large firms. Varga (2000) uses the Griliches-Jaffe knowledge production function to try to model agglomeration. He develops a hierarchical linear model by modeling each α, to include the dependence of the knowledge transfer on the concentration of high technology production and business services.

Keilbach (2000) has taken a different path. Incorporating the work of Krugman (1991) and Fujita et al. (1999), he builds a dynamic model of regions using the endogenous growth model including human capital and knowledge spillovers, to be able to separate the effects of spillover and agglomeration. The model builds a class of discrete dynamic systems, an n-dimensional array of sites, each with local rules as well as global rules. Assuming the initial endowments of capital and labor are identical in each region and that the distribution of knowledge is random, that capital moves globally, labor migrates locally, but human capital spills over, Keilbach observes agglomeration under assumptions of increasing returns to R&D only. The model demonstrates a self-reinforcing structure where labor agglomerates no matter what, but agglomerates quicker with increasing returns to R&D.

The various authors above, as well as others, have considerably moved forward our understanding of the nature of knowledge spillovers. These studies demonstrate that knowledge, as an output of an organization, has unique qualities that render knowledge producing organizations not just like any other large organization that purchases inputs locally and employs a large of number of people. Rather there are significant external benefits of knowledge production in the form of spatial spillovers that lead to higher levels of innovative activity among other firms within the region.

There are, however, some limitations in the use of this approach for estimating the contribution of universities to regional economic development. These include measurement and data issues, the limited scope of potential outputs and impacts stemming from universities, and thus the limited ability to separate different ways that universities contribute to regional economic development.

The primary challenge with using these types of models is how to measure the dependent variable, innovation. Jaffe (1989) quotes Griliches as saying, "The dream of getting hold of an output indicator of inventive activity is one of the strong motivating forces for economic research in this area." Since we do not know how to measure innovation directly, we use proxy indicators, each with their own inherent challenges.

Varga (2000) and Acs, Audretsch and Feldman (1994) use a one-time cross section data set from the Small Business Administration on new product introductions. They reason that these innovations had market value since companies introduced them and that this was a better measure than patents or other pre-market indicators. From a company point of view, product introductions are still indicators of "probable" market value. Until sales of a product are known, the market value is still a prediction. So, while it is true that product introductions, being further down the product development chain than patents, are probably better indicators of innovations with market value, they are still predictors, not measures. The other significant issue with this data set is that it is a one-time indicator, constructed in 1982, and now highly dated.

Jaffe (1989) and Jaffe, Trajtenberg and Henderson (1993) use the number of patents as their dependent variable. There are a lot of issues with this indicator, as Jaffe recognized at the time. For instance, there are factors outside knowledge generation that affect the number of patents that may arise from a given piece of research and development.

First, not all innovation is patentable. Other types of innovation not included in patents are codified knowledge embodied in copyrights, trade secrets and scientific papers as well as tacit know-how and shared expertise. Since the transmission of tacit information is an important explanation of why spillover has local effects (as compared to patents that can be licensed worldwide), our inability to measure this dimension is a significant handicap.

Second, especially within universities, changes in patenting policies and the university's fiscal environment significantly affect the number of patents applied for and granted. Thursby and Thursby (2000), for instance, have shown that the recent growth in licensing activity at U.S. research universities has been based on input growth (i.e. more disclosures) of lowering quality and an increase in the propensity of administrators to patent and license faculty inventions as a revenue raising strategy.

In fact, the general hypothesis has been that patents are a proxy for inventive output and patent citations are a proxy for knowledge flows or spillover, the real source of innovation. Recent work (Hall, Jaffe and Trajtenberg, 2000) strongly suggests that patent citations are well correlated with the market value of knowledge and are the best indicator of innovation and knowledge spillover. To date, patent citations have not been used in the knowledge production function, although Jaffe and Trajtenberg (1996) do use them to find that diffusion of knowledge is geographically localized.[3]

The second major limitation of this approach for our purposes is that while it yields estimates on some of the outputs of universities, i.e. technological innovation, it does not take into account other outputs of universities discussed in section 2 above – human capital creation, building regional capacity, stimulating business start-ups, and the regional milieu effect – that potentially have regional economic development impacts.

4 A Quasi-Experimental Approach

Quasi-experimental designs are best described in comparison to true experimental designs. The hallmarks of true experimental designs are that the researcher can manipulate how and which cases receive a "treatment", such that the treatment can be randomly assigned to cases drawn from a sample of a given study population. Randomization means that probabilistically there should be no systematic difference on any rival causal factors between those cases receiving the treatment and those that do not. Thus any differences in the dependent variable between the treatment and non-treatment groups can normally be attributed to the treatment effect.

In field settings as opposed to laboratory settings, the ability of researchers to randomly select cases for treatment is rare. Instead they must accept the naturally occurring variation in a given treatment variable, in this case the regional distribution of universities by size and type. In other cases, it may be technically feasible for researchers to manipulate the selection of cases for treatment or nontreatment, but it is ethically prohibited. Quasi-experimental designs are a class of designs in which the researcher strategically manipulates the study population, the time period, and the sampling so as to construct control groups that enable one to control for some of the rival factors that cannot be explicitly included as variables in a statistical model. Cook and Campbell (1979) and Shadish, Cook and Campbell (2002) provide comprehensive and detailed descriptions of quasi-experimental designs.

The control group cases can not be assumed to be equivalent to the treatment cases in all respects except for the treatment variable itself. However, such selection differ-

[3]A third measure of innovation that has been used is R&D intensity. This is measured by the number or percentage of R&D employees. Keilbach, when testing his model on 327 Kreise (districts) of West Germany, used R&D employment as a proxy for R&D intensity.

ences can be taken into account by measuring and comparing gain scores – differences in the outcome variable(s) between a pretest and posttest – instead of just comparing posttest scores.

In the context of conducting research on the relationship between knowledge production in a region and regional economic development outcomes, the presence of research universities or other significant knowledge-producing organization in a region would represent the treatment variable. The dependent variable would be the gain, or difference, of some meaningful economic development outcome over a pertinent time period. The control group would consist of regions that did not have research universities (or other significant knowledge-producing organizations). Additional control groups may be selected so as to effectively control for other factors that might also explain variations in the dependent variable in addition to the presence or absence of a research university. Thus, we might select two treatment groups, one with small- to medium-sized regions with research universities and one with large-sized regions with research universities, and two control groups (small to medium without research universities, and large without research universities). We then compare the gains for all four groups, to take into account the effect of agglomeration economies and its interaction with the presence of universities.

It is important to distinguish quasi-experimental designs from more commonly used large sample cross-sectional statistical analyses. In the latter, the researcher would randomly select a large sample of regions from the full population available, enter measures on a number of variables that the literature has suggested may explain the dependent variable into a multiple regression model, and then estimate the model. The interpretation of the effect of research universities would be based upon the significance, sign, and magnitude of the coefficient estimate on the measure(s) selected for the presence or level of activity of a research university in the region. In effect, the researcher statistically controls for all other factors by entering these explicitly into the model. In contrast, quasi-experimental designs first attempt to control for other putative factors by the strategic design of treatment and control groups such that for some putative causal variables there is no variation allowed. For others there is an attempt to maximize variation. Only after these possibilities are practically exhausted does the researcher introduce statistical controls.

Although quasi-experimental designs have been used occasionally in published regional research (e.g. Isserman, 1987, Isserman and Merrifield, 1987), to the authors' knowledge, they have not been utilized in attempts to estimate the contribution of knowledge-producing organizations to regional economic development.

4.1 Study Objectives, Unit of Analysis, and Study Population

The objectives of this study are (1) to estimate the magnitude of the contribution of universities to changes in regional economic well-being, controlling for other factors; and (2) to try to separate the regional economic development impacts of different functions of universities.

The unit of analysis in our study is the metropolitan statistical area (MSA). All variables are measured for the MSA. The study population consists of all 312 MSAs in the U.S. on the basis of their 1990 Census geographical definitions.[4] The temporal period is from 1969 to 1998.

4.2 Measures of Regional Economic Development

Our measure of regional economic development is average annual earnings per worker. This contrasts with many studies that use per capita income as a measure of regional economic well-being. The most important difference between the two measures is that average earnings per worker takes into account only earned income, while per capita income includes unearned income including dividends, rent, interest, and transfer payments. These unearned sources of income are particularly significant in regions with a large number of retirees. Also, average earnings per worker takes into account only the economically active persons in the denominator. Finally, average earnings per worker focuses on the quality of jobs in a region as the most important dimension of improvement in regional economic well-being.

To separate out changes in national macroeconomic conditions over the time period, including changes in the value of the dollar, we construct a normalized index for each MSA by dividing the MSA's average earnings per worker by the U.S. average earnings per worker for the same year, and then multiplying this ratio by 100. Thus, an index value of 110.0 for a particular MSA means that its average earnings per worker for that year is 10.0 percent higher than that for the nation.

The dependent variable is calculated as the difference in the index value for a given MSA between two years. Thus, if a particular MSA had an index value of 110.0 in 1969, and a value of 120.0 in 1999, then the value of the dependent variable would be 10.0. Of course it is possible for MSAs to have negative values on the dependent variable.

One benefit of using change in the index value is that it helps control for some local factors that are endemic to particular areas. For example, in many small MSAs with large universities, the average earnings per worker is distorted downward by a relatively large number of students employed in low-wage, part-time jobs. This distortion is minimized when the difference, rather than the level, of average earnings per worker is used.

4.3 Measures of University Presence

We measure the presence of universities in an MSA in three alternative ways, in order to test specific hypotheses described below. Our first measure is whether there is a top 50 research university located within the MSA at the beginning of the respective time period. A top 50 designation is based upon rankings of universities in terms of total research expenditures, compiled by the National Science Foundation on an annual basis[5].

[4]We did not include five MSAs in our study population because they were considered outliers because of their size or their physical isolation: Anchorage (Alaska), Chicago, Honolulu, Los Angeles, and New York.

[5]National Science Foundation, CASPAR database, 2001.

The second measure is the sum of the total research expenditures over all universities located within the MSA for a given annual period. The third measure is the sum of all degrees awarded in all institutions of higher education located within the MSA, for a given year. This third measure directly takes into account the magnitude of the human capital creation, or the teaching function of higher education institutions, separate from their research and economic development functions.

4.4 Control Variables

There are, of course, a number of other causal factors that may help to explain variation in the magnitude of change in a region's economic well being. First are agglomeration economies, measured by the total MSA employment at the beginning of the time period. We also use three MSA size categories: small, medium, and large employment levels to partially define control groups.[6]

Other factors include:

Region of U.S. The region of the U.S. (Northeast, Midwest, South, and West) is used to control for broad shifts in the regional distribution of population, employment, and capital investment from the Northeast and Midwest to the South and West over much of the time period. Region of U.S. is measured as dichotomous variables and enter into the statistical model as three dummy variables.

Industry research activity. The research activity of industry is measured as the number of industry R&D facilities located in the MSA. This variable controls for other R&D activity outside universities that may stimulate regional economic development.[7]

Industry structure. We include three dimensions of the industry structure of MSAs: percent earnings in manufacturing, percent earnings in business services, and change in percent earnings from manufacturing over the time period. These variables take into account that concentrations of manufacturing and business services may increase a region's capacity for regional economic development.

Entrepreneurial Activity. Lacking better measures for all regions of the U.S. over the time period of the study, we use as a proxy the percent earnings in the MSA from proprietorships (self-employed).

Base-year level of average earnings per worker. To control for a possible endowment effect (the rich get richer ...), we include the average earnings per worker at the start of the time period.

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[6]The size categories chosen for 1969 are: (i) under 75,000 employment, (ii) 75,000 to 499,999, and (iii) 750,000 and over. The size categories for 1986 are: (i) less than 250,000 employment, (ii) 250,000 to 999,999, and (iii) 1,000,000 and over. This yielded 160, 104, and 25 MSAs, respectively in the three size categories in 1969, and 192, 59, and 27 MSAs, respectively, in 1986.

[7]We relied on the listings in *Industrial Research Laboratories of the U.S.* (New York: R.R. Bowker & Co., 1970, 1985).

4.5 Hypotheses and Designs To Test Them

The first hypothesis is that research universities contribute significantly to regional economic development, controlling for other factors. This is tested in two ways. First, if true, then the gain in average earnings per worker should be higher for regions with top 50 research universities than those without. We thus compare the mean gain in average earnings per worker in regions with research universities against the same dependent variable for regions without top 50 research universities, controlling for size of MSA, region of the U.S., and industry structure, and apply a difference of means test for statistical significance. Second, in a multiple regression model, the coefficient on total university research expenditures in the region should be positive and significant, with other putative causal factors included as control variables.

The second hypothesis is that universities' technology development activity contributes significantly to regional economic development. Without a good direct measure of university technology development for all institutions of higher education within the MSA, we employ one of the strategies of quasi-experimental designs, i.e. manipulation of the time period. We split the full time period into two parts: 1969 to 1986 and 1986 to 1999. The rationale for this is that around the middle of the 1980s, many universities started to incorporate economic development missions, both in response to reductions in federal research support and the Bayh–Dole Act (Feller, 1990), as well as the initiatives of many state legislatures promoting universities as economic development actors in response to the 1981–82 recession and lagging competitiveness. Around the mid-1980s, universities began creating technology transfer offices to support patenting and licensing activities, building incubators and research parks and, occasionally, creating or investing in venture capital funds. Thus, if universities' involvement in technology development in various forms has been an important contributor to regional economic development, then the difference in the dependent variable (gain in average earnings per worker) between regions with research universities and those without should be larger in the 1986 to 1999 period compared to the 1969 to 1986 period.

The third hypothesis is that human capital creation (teaching) and the milieu functions are important contributors to regional economic development, controlling for the magnitude of research and technology development activity. Human capital creation and milieu, together, are measured by the number of degrees awarded annually by all institutions of higher education in the region. If this is true, then the coefficient in the multiple regression model will be positive and significant in both time periods.

The fourth hypothesis we investigate is whether agglomeration is more important than the presence of research universities as a contributor to regional economic development. If this is true, then the coefficient for size of MSA will be positive and significant, and stronger than coefficients on measures of university presence variables in the regression model, and more so in the 1986 to 1999 period than the earlier period.

The fifth hypothesis is a variant on the fourth: that there is interaction between presence of research universities and agglomeration. More specifically, our hunch is that they are substitutes. If this is true, then the effect of research universities will be smaller the larger the MSA. This is tested by comparing the difference of means between MSAs with top 50 research universities against those without top 50 research universities, by size class. The differences should be largest for the smallest class of MSAs, and smallest for the largest class of MSAs. These differences should also be more prominent in the 1986 to 1999 period than the 1969 to 1986 period.

5 Empirical Results

As stated above, we conducted two different types of analysis of the data. The first is a set of difference-of-means tests between MSAs with and without top 50 research universities, overall, and classified by a number of control variables. These difference-of-means tests are done for each of the two separate time periods to be able to compare for temporal differences. The results are shown in Tables 1 and 2, respectively.[8]

There are no significant differences in change in average earnings per job between MSAs with top research universities and those without, for the 1969–1986 period. These results hold overall, and for each MSA size category, location, and type of industry structure. Two-way cross-tabs combining MSA size categories, location, and industry structure also showed that the presence of a research university was not associated with change in average earnings per job, except for the one case: large MSAs located in the South. Here, however, the small number of such MSAs without research universities outperformed those with top research universities.

The results for the 1986–1998 period tell a quite different story. In the entrepreneurial university period, the differences between MSAs with, and without, top research universities are significant and positive for the overall study population. When we disaggregate by type of MSA, we get the same results for small MSAs, those in the Northeast, South, and West, and with both high and low percentages of manufacturing. Within small MSAs, the positive presence of research universities is most prominent in the West.

The second type of analysis is based upon OLS multiple regression. Separate models are estimated for each of the two time segments. These results are shown in Tables 3 and 4.

During the 1969–1986 period, neither total university research expenditures nor the total number of degrees awarded are statistically significant in explaining variation in the MSAs' change in average earnings. The factors that are significant are: location in the Midwest (negatively related), location in the South (positively related), MSA size (positive), average earnings per job at the start of the period (negative), proportion of total earnings from the manufacturing sector (negative), proportion of self-employed earnings (negative), number of private R&D labs (positive), and the change in percent earnings from manufacturing over the time period (positive). The results suggest that general regional macroeconomic conditions, agglomeration economies, and aspects of industry structure, rather than the presence of universities, were the most important factors determining gain in regional economic well-being during this

[8] In a number of cases the n of one of the groups was small, a condition which often leads to unequal group variances. In these cases we used the approximate t statistic (SAS Institute, 1991).

Table 1: Change in Average Earnings/Job, 1969–86

Type of Area	MSAs with RU Mean	N	MSAs without RU Mean	N	Difference
All	−1.2	37	−0.67	252	−0.53
Small	−2.72	11	−1.21	149	−1.52
Medium	−1.8	13	−0.13	91	−1.67
Large	0.68	13	1.92	12	−1.24
Northeast	−0.72	6	−2.21	33	1.49
South	4.37	9	4.18	109	0.18
Midwest	−6.02	11	−6.21	62	0.19
West	−1.2	11	3.48	48	2.28
Low Mfg	0.05	17	0.83	105	−0.78
High Mfg	−2.26	20	−1.74	147	−0.52
Small, Low Mfg	−2.45	7	−0.72	68	−1.73
Medium, Low Mfg	−0.04	6	3.38	35	−3.45
Large, Low Mfg	4.55	4	8.77	2	−4.22
Small, High Mfg	−3.2	4	−1.62	81	−1.58
Medium, High Mfg	−3.32	7	−2.33	56	−0.99
Large, High Mfg	−1.03	9	0.55	10	−1.59
Small, Northeast	−7.9	1	−5.24	14	2.66
Small, South	3.88	3	3.95	66	−0.07
Small, Midwest	−5.26	4	−5.8	37	0.54
Small, West	−4.23	3	−4.78	32	0.55
Medium, Northeast		0			
Medium, South	4.95	4	3.99	40	0.96
Medium, Midwest	−6.26	5	−7.18	21	0.92
Medium, West	−2.99	2	−5.05	4	−1.94
Large, Northeast	0.72	3	1.33	5	−0.61
Large, South	3.92	2	11.92	3	−8.01*
Large, Midwest	−6.99	2	−5.05	4	−1.94
Large, West	2.86	4	1.75	2	1.1

period. Where knowledge producing activity mattered, it was outside universities.

The results are sharply different for the 1986–1998 period. Total university R&D activity is significant and positive, while total number of degrees awarded is significant and negative. Location still matters, but now the advantage is only for MSAs in the Northeast. MSA size is still significant and positive, and average earnings per job at the start of the time segment is still significant and negative. The effect of industrial structure attributes has changed. The relative size of the business services sector – a measure of the development of the business infrastructure – is now significant and positive, but the relative size of the manufacturing sector and the self-employed sectors are not significant factors. Neither is the number of private R&D labs significant in this later period. It should also be noted that the overall explanatory power of the model in the second time segment is lower than in the earlier one as indicated by the R-squared.

Table 2: Change in Average Earnings/Job, 1986–98

Type of Area	MSAs with RU Mean	N	MSAs Without RU Mean	N	Difference
All	3.37	36	−4.61	242	7.98**
Small	0.91	9	−5.63	185	6.54**
Medium	0.02	13	−2.77	46	2.8
Large	8.06	14	4.93	13	3.13
Northeast	7.38	8	−1.1	32	8.47*
South	1.88	10	−4.48	105	6.36**
Midwest	−3.08	9	−5.81	61	2.73
West	7.91	9	−5.82	44	13.72**
Low Mfg	−0.79	17	−4.49	116	5.28**
High Mfg	5.68	19	−4.72	126	10.4**
Small, Low Mfg	−3.03	6	−5.33	89	2.3
Medium, Low Mfg	0.89	5	−2.58	22	3.47
Large, Low Mfg	4.51	6	1.99	5	2.52
Small, High Mfg	8.79	3	−5.92	96	14.7**
Medium, High Mfg	−0.52	8	−2.96	24	2.44
Large, High Mfg	10.72	8	7.37	6	3.34
Small, Northeast	−3.37	1	−4.21	22	0.84
Small, South	−2.4	3	−5.71	81	3.31
Small, Midwest	−2.55	3	−5.7	47	3.16
Small, West	13.2	2	−6.26	35	19.46**
Medium, Northeast	5.81	3	2.83	7	3.98
Medium, South	2.29	4	−0.61	21	2.9
Medium, Midwest	−4.9	4	−7.82	11	2.92
Medium, West	−3.34	2	−6.94	7	3.59
Large, Northeast	11.23	4	12.26	3	−1.39
Large, South	5.62	3	1.67	3	3.96
Large, Midwest	−0.23	2	−0.08	3	0.15
Large, West	10.29	5	5.78	2	4.51

6 Conclusions and Suggestions for Further Study

Our first hypothesis, that research universities contribute significantly to regional economic development, controlling for other factors, was not supported throughout the full period of study. However, our second hypothesis, that it is the universities' economic development activities that matter most, is confirmed by the data. In the earlier 1969–1986 period, the presence or absence of a top 50 research university did not affect the gain in average earnings per worker, while it is a significant factor in the 1986–1998 period. These activities were generally absent in the pre-1986 time period and quite prevalent in the latter period.

Our third hypothesis is that the human capital creation and milieu functions of the university are important contributors to regional economic development. Since these

Table 3: Multivariate Regression Model Results: 1969–1986

Dependent Variable: Change in Average Earnings 1969–1986

Total DF	311	Root MSE	5.40
R-squared	0.554	Adj R-Sq	0.5361
F Value	30.96	Pr > F	<0.0001

Variable	Parameter Estimate	Standard Error	T value	Pr > t	Tolerance
Intercept	34.36	3.61	9.52	<0.0001	
UNRD72	−0.04	0.04	−1.02	0.31	0.23
Degree72	−0.19	0.19	−1.03	0.30	0.15
West	−2.34	1.28	−1.83	0.07	0.36
Midwest	−4.02	1.09	−3.69	0.00	0.42
South	2.27	1.09	2.08	0.04	0.33
Employ68	0.00	0.00	3.88	0.00	0.29
AVGEARN69	−0.24	0.03	−7.20	<0.0001	0.43
MFG_EARN69	−0.07	0.03	−2.13	0.03	0.45
BUS_EARN69	−0.30	0.22	−1.37	0.17	0.77
Prop_Earn69	−0.85	0.10	−8.30	<0.0001	0.75
LABS70	0.04	0.01	2.86	0.00	0.53
CHMFG69_86	0.34	0.07	4.53	<0.0001	0.53

Table 4: Multivariate Regression Model Results: 1986–1998

Dependent Variable: Change in Average Earnings 1986–1998

Total DF	311	Root MSE	5.90
R-squared	0.371	Adj R-Sq	0.345
F Value	14.68	Pr > F	<0.0001

Variable	Parameter Estimate	Standard Error	T value	Pr>t	Tolerance
Intercept	14.02	4.30	3.26	0.00	
UNRD86	0.02	0.01	2.35	0.02	0.32
Degree86	−0.39	0.16	−2.40	0.02	0.15
West	−4.20	1.26	−3.33	0.00	0.45
Midwest	−4.80	1.15	−4.18	<0.0001	0.46
South	−4.22	1.12	−3.77	0.00	0.37
Employ86	0.00	0.00	4.14	<0.0001	0.21
AVGEARN86	−0.20	0.04	−5.28	<0.0001	0.53
MFG_EARN86	0.03	0.04	0.82	0.41	0.58
BUS_EARN86	1.38	0.21	6.40	<0.0001	0.67
Prop_Earn86	−0.19	0.15	−1.26	0.21	0.67
LABS85	0.01	0.01	1.10	0.27	0.20
CHMFG86_98	0.10	0.06	1.83	0.07	0.79

factors are present throughout the two periods, and the university was not found to be a significant factor in the earlier period, it appears that these functions are not as important as we had thought originally. That MSAs with research universities outperform MSAs without top research universities, in the age of the knowledge-based economy and the "entrepreneurial university," controlling for other factors, is expected. That the presence of universities did not matter one way or the other in the earlier 1969–1986 period, supports the view that the teaching and milieu functions are not as important as the research and economic development functions of universities, since the former functions did not appreciably change over the full period, while research activity and economic development increased dramatically from the early to the later period. Indeed, the negative relationship between the number of degrees awarded by all institutions of higher education in the MSA and the dependent variable for the 1986–1998 period adds further support to this view. The negative relationship can be interpreted as a tendency toward an oversupply, or saturation, of highly educated workers in the average regional labor market. Since we do not have any indicator of the milieu function independent of teaching activity, unfortunately we cannot separate these factors in the interpretation of the results.

Our fourth and fifth hypotheses, the questions of whether the agglomeration economies are more important than research universities, and whether there research universities may serve as a substitute for agglomeration economies, have been debated in the literature for some time. Our results provide mixed evidence. On the one hand, in the 1986–1998 period, the only MSA size category for which the presence of research universities made a significant difference was small MSAs, suggesting a substitute effect. On the other hand, the coefficient estimate for MSA size in the regression model for both time periods indicates that agglomeration matters, independent of the presence and size of the university sector. It may be that both of these seemingly contradictory results are true; research universities in small areas can provide a number of external benefits that urban agglomerations generally provide.

Finally, although the presence of research universities and their scale of research activity are statistically significant factors in explaining gains in average earnings per job among MSAs in the later period, the strength of the causal relationship is quite modest. Controlling for other factors, it would have taken an increase of $10 million in research expenditures among universities in an "average" MSA to increase the index of average earnings per job by 0.2. To give these numbers some perspective, the "average" MSA had $30.7 million in R&D expenditures in 1986. If the universities in this hypothetical MSA had been able to increase their R&D expenditures by $10 million more (about a 33 percent increase), the MSA would have increased its index from 100.0 to only 100.2.

Overall, our results provide additional support to the view that universities' research and technology development activities do indeed generate significant knowledge spillovers that are captured within the regional environment, and result in enhanced regional economic development. Yet the magnitude of the contribution of those activities is small compared to other factors.

It would be interesting to conduct a similar study of the contributions of institutions of higher education to regional economic development in European countries.

A number of EU countries recently have had changes in higher education policy that would encourage universities to become more entrepreneurial and to become more engaged with the private economy. A study conducted in several years would allow enough time to observe if there have been changes in the magnitude and type of economic impacts of universities and other institutions of higher education on their respective regions. Such a comparative study would allow us to test the hypothesis that there is convergence, albeit with a time lag, between the role and impacts of universities in parts of Europe and in the U.S.

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Appendix 1: Average Earnings by Job by Type of Region

Area	Change 69–86	Change 86–98	Change 69–98
I, Raleigh-Durham, NC	12.7	4.9	17.6
II, Richmond, VA	7.5	1.1	8.6
III, Southeast United States	6.1	0.1	6.2
IV, Small-Medium MSAs with Research Universities			
Ann Arbor, MI	−9.8	−4.6	−14.4
Boulder, CO	−6.1	19.6	13.5
Bryan-College Station, TX	0.1	−6.6	−6.5
Champaign-Urbana, IL	−6.8	−5.4	−12.2
Gainesville, FL	5.2	0.2	5.4
Madison, WI	−12.3	1.8	−10.5
Raleigh-Durham, NC	12.7	4.9	17.6
State College, PA	−7.9	−3.4	−11.3
Tallahassee, FL	3.2	4.8	8.0
Tucson, AZ	−6.3	−5.0	−11.3
Average	−2.8	1.1	−1.7
V, Large MSAs with Research Universities			
Atlanta, GA	6.7	9.7	16.4
Austin, TX	10.9	13.3	24.2
Baltimore, MD	1.2	0.5	1.7
Boston, MA	5.7	12.9	18.6
Columbus, OH	−7.5	−0.7	−8.2
Minneapolis-St. Paul, MN	−3.0	2.3	−0.7
Pittsburgh, PA	−5.0	−0.6	−5.6
San Diego, CA	3.6	−2.8	0.8
Seattle, WA	−6.2	15.2	9.0
St. Louis, MO	−1.9	−2.7	−4.6
Average	0.6	4.7	5.3
VI, Small-Medium MSAs without Research Universities			
Albuquerque, NM	−1.9	−5.1	−7.0
Burlington, VT	−3.4	0.9	−2.5
Charlottesville, VA	4.5	4.8	9.3
Columbia, MO	−1.1	−0.4	−1.5
Columbia, SC	5.9	−2.1	3.8
Eugene, OR	−13.3	−2.3	−15.6
Knoxville, TN	4.8	−3.4	1.4
Lexington, KY	4.3	1.1	5.4
Lincoln, NE	−4.3	−0.9	−5.2
Richmond, VA	7.5	1.1	8.6
Tuscaloosa, AL	15.7	−11.9	3.8
Average	1.7	−1.7	0.0
VII, Large MSAs without Research Universities			
Charlotte, NC	8.8	8.1	16.9
Dallas, TX	11.9	9.2	21.1
Denver, CO	5.5	6.8	12.3
Detroit, MI	−5.8	−2.1	−7.9
Indianapolis, IN	−5.4	1.1	−4.3
Kansas City, MO	−0.3	−1.8	−2.1
Milwaukee, WI	−8.8	0.5	−8.3
Portland, OR	−7.1	4.8	−2.3
Sacramento, CA	−4.5	−1.7	−6.2
Tampa-St. Petersburg, FL	0.2	3.8	4.0
Average	−0.5	2.9	2.4